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THE

AMERICAN

JOURNAL OF SCIENCE.

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THIRD SERIES.

VOL. XLVII.—[WHOLE NUMBER, CXLVII.]

No. 279.—MARCH, 1894.

NEW HAVEN, CONN.: J. D. & E. S. DANA.

1894.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

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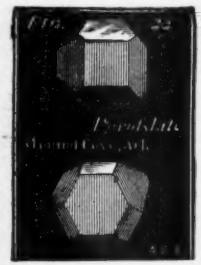

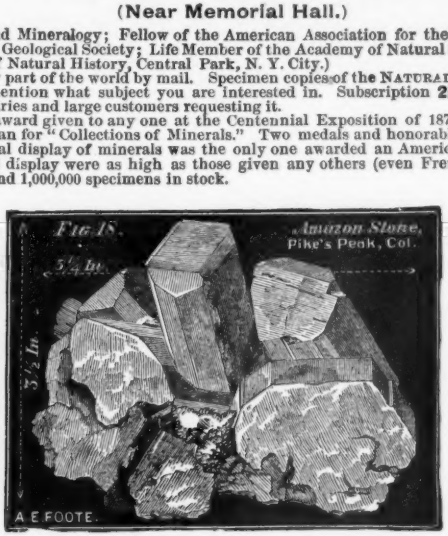

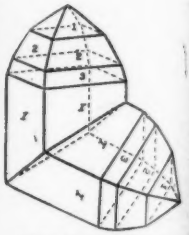

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AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XVII. — *Continuity of the Glacial Period;* by G. Frederick Wright.

Since the appearance in this Journal, for November, 1892, of my paper upon "The Unity of the Glacial Epoch," many important facts bearing upon the subject have come to light, especially in respect to the extent of preglacial erosion in the Ohio Valley. In my report upon "The Glacial Boundary in Western Pennsylvania, Ohio, Kentucky, Indiana and Illinois," published by the United States Geological Survey in 1891,* it was maintained that the erosion of the rocky gorge of the Ohio River and its tributaries was *pre*glacial. In opposition to this view, Professor Chamberlin, in the Introduction accompanying my report, maintained that the most important part of this rock erosion was *inter*glacial.

To make this point clear it should be stated that the upper portion of the Ohio River and its northern tributaries is characterized by a series of gravel deposits containing Canadian pebbles, resting upon rock shelves from 200 to 300 feet above the present river, and from 250 to 350 feet or more above the rock bottom of the river; while there is a lower series of gravel terraces, rising in places to 130 feet above the river, which is traceable up the streams to the moraine first described by Professor Lewis and myself in 1881.† The relation of

* Bulletin No. 58.

† The accompanying map (Fig. 1) to which frequent references will need to be made, shows the 500-foot and the 1000-foot contours of the Ohio Valley; also the boundary of direct glacial action. The figures give the elevation above the sea. Those along the river refer to the low-water mark. In the lower right hand corner is a typical section of the Allegheny showing the rock channel and the high-level terraces.

this portion of the rock gorge to Glacial movements is one of the principal points in controversy. My contention has been that this part of the rock gorge was preglacial; while in the Introduction referred to, Professor Chamberlin states (p. 35) his position as follows:

"The higher Glacial gravels antedated those of the moraine-forming epoch by the measure of the erosion of the channel through the old drift and the rock, whose mean depth here is about 300 feet, of which perhaps, 250 feet may be said to be rock. The excavation that intervened between the two epochs in other portions of the Alleghany, Monongahela, and Upper Ohio Valleys is closely comparable with this."

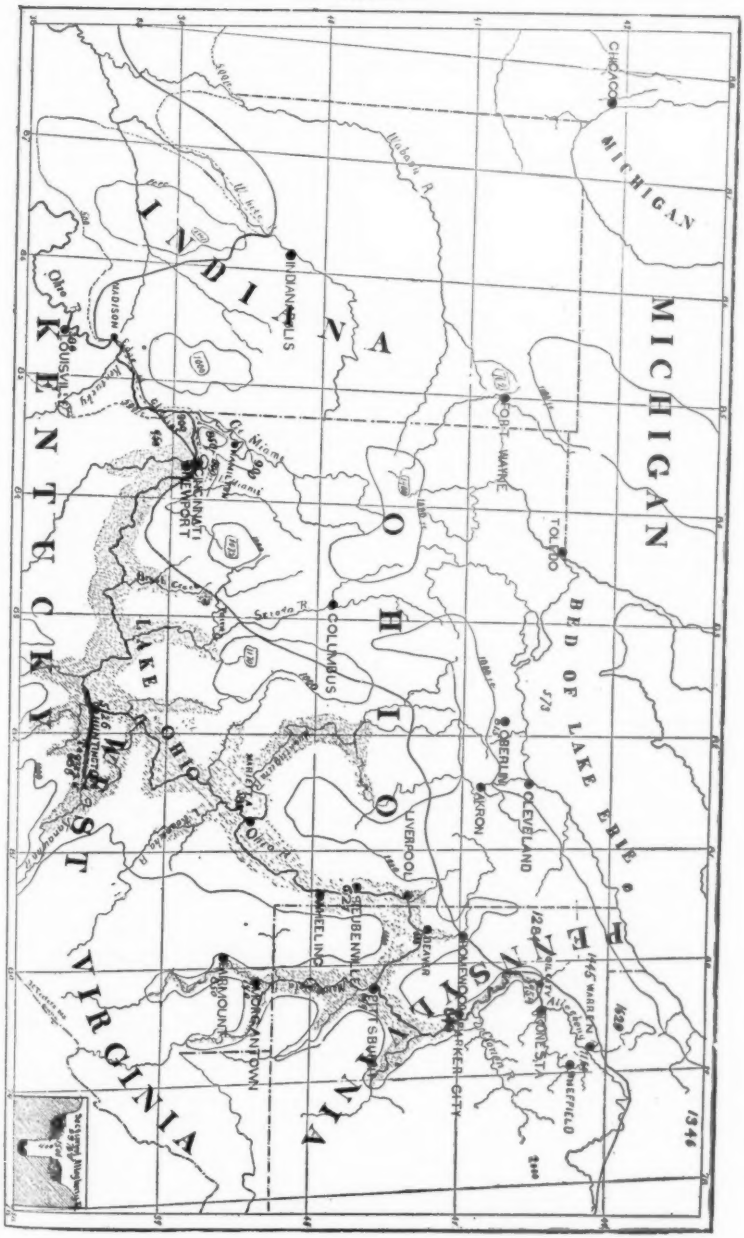
In this Journal, for March, 1893, in a paper replying to mine of the previous November, Professor Chamberlin reiterates in the strongest manner his adherence to his previously expressed views concerning the interglacial date of this rock erosion in the Ohio Valley. Thus he writes:

"These terraces I have maintained* were produced at a time of base level degradation, which in its later stages was contemporaneous with the earlier ice incursion whose water bore gravels down the Allegheny, Upper Ohio and some adjacent streams, and formed the 40 or 50 feet of capping which lies upon the rock benches that constitute the body of the terraces. I have argued that subsequent to this the land was elevated and the lower newer steep-sided gorges of the Allegheny and neighboring streams were cut to a depth that may be roundly stated as 250 feet, and that subsequent to this the later ice incursion formed the outer moraine of the region. From the outer side of this moraine Glacial streams bore their sands and gravels down the Allegheny gorge cut during the interglacial interval. The evidence of this, gathered in a joint study by Mr. Gilbert and myself, may be found in Bulletin 58, U. S. Geol. Surv., pp. 32–36. I therefore argue that between the time when the Glacial gravels were deposited on the high terraces and the incursion of the later ice there was a cutting of the gorge to the depth of 250 feet roundly speaking. I regard this gorge-cutting as a *minimum* measure of the interval between the two ice incursions."

During the past year I have devoted as much time as I could spare from other duties and other fields of investigation to the collection of additional facts bearing upon the solution of this important problem. In December, 1892, under guidance of Mr. Richard R. Hice, of Beaver, Pa., I examined the valley of the Big Beaver between the Ohio and the Glacial boundary, with the result of finding, just below the line of

* Bulletin 58, U. S. Geol. Surv., pp. 20–38.

FIGURE 1.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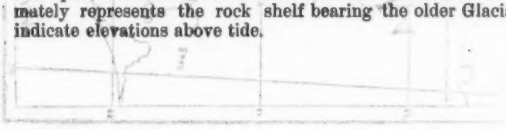
Allegheny R.
Beaver R.
Grand R.
Cuyahoga R.
Sandusky R.
Maumee R.
Ill. Lake
Miami Canal
Miami Canal
Ohio Canal
Ohio Canal
Ohio

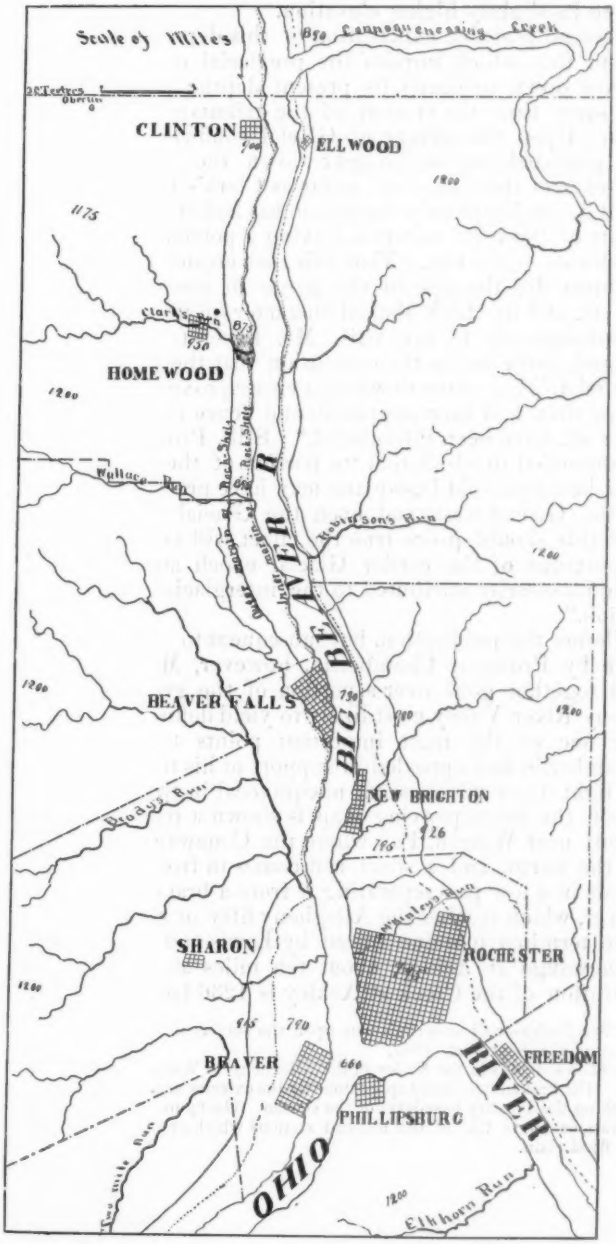
direct glaciation, a buried channel which appeared to be preglacial. Of this I wrote a brief account in the March number of the American Geologist for 1893 (pp. 198–199). The accompanying map (Fig. 2) will explain the situation.*

The buried channel occurs at Homewood, on the Big Beaver, about nine miles from its mouth, and where Clark's Run joins it from the west. The Big Beaver is here walled in by thick and extensive deposits of compact Homewood sandstone which is extensively quarried in the vicinity. The river occupies a gorge in the sandstone whose perpendicular descent from the rock shelf to the surface of the water ponded back by the dam at Beaver Falls is, as measured by lock level, 145 feet; but the rock bottom, as determined in building the railroad bridge at Ellwood Junction, two miles above, is, according to data gathered by Mr. Hice, sixty feet below the bottom of the Beaver. Just how deep the water in the pond is I am unable to say, but probably not more than ten or twelve feet. This will make the present depth of the gorge 225 feet. Above Clark's Run this shelf bears a vast amount of sand, gravel, and bowlders derived from the wash of the glaciated region, whose boundary approaches to within two or three miles of the locality. Many sandstone bowlders several feet in diameter occur in this deposit. Clark's Run, which enters the Beaver at right angles, has cut a gorge with a V-shaped mouth through the Homewood sandstone nearly to the level of Beaver Creek. The north side of this wide, deep side channel of Clark's Run is filled in with a water deposit, consisting of stratified sand and gravel, capped by three or four feet of coarser deposits containing large bowlders. This has been resorted to for sand and gravel until great masses have caved down, and obstructed the road which passes along its foot up the run. We were unable to determine just the depth to which this deposit extends; but it is certainly from sixty to eighty feet deep, and the angle between the gravel pits and the Big Beaver is entirely occupied by it. So completely was this filled in at that point, that it is also difficult to tell just how wide the mouth of the V-shaped opening was. On the south side of the gorge of Clark's Run the jagged rocks are exposed from top to bottom, although near the mouth there are some remnants of gravel at the top, showing that it had originally filled the whole space. The shelf south of Clark's Run presents a great contrast to that north of the



* A portion of the valley of Big Beaver Creek above its junction with the Ohio. The broken lines approximately mark the limit of the later Glacial terrace. The space between the broken line and the continuous line outside of it approximately represents the rock shelf bearing the older Glacial gravel. The figures indicate elevations above tide.

FIGURE 2.


Scale of Miles
CLINTON
ELLWOOD
HOMEWOOD
BEAVER FALLS
NEW BRIGHTON
SHARON
ROCHESTER
BEAVER
FREEDOM
PHILLIPSBURG
BIG BEAVER R
RIVER
OHIO
Wallace Run
Brodys Run
Elkhorn Run
1175
1200
750
660

run, being wholly devoid of drift material. Possibly this is due to its slightly higher elevation.

I see no probable explanation of this deposit in Clark's Run except that which implies the preglacial erosion of the Big Beaver down to nearly its present depth; thus permitting at the same time the erosion of the tributary valley of Clark's Run. Upon the advent of Glacial conditions the wash from the glaciated region brought down the material which is spread over the rock shelf as far as Clark's Run, and partially filled it. Subsequently the stream has had time only to re-erode a part of the loose material, leaving a portion of it still on the north side of the run. That this rock erosion was very ancient is shown by the size of the gorge in comparison with the stream, and by the V-shaped character of its mouth.

Subsequently to my visit, Mr. Leverett looked over the ground, and came to the conclusion that the ice of "the later incursion" had come down into closer proximity to this buried gorge than had been supposed, and hence that the gorge may, after all, have been interglacial.* Still, Professor Chamberlin is compelled to admit that "a portion of the excavation of the rock below the old base-plane may have preceded the incursion of the Glacial wash and even the Glacial period;" and that "If this should prove true the effect will be to extend [?] the importance of the earlier Glacial epoch and to reduce the time necessarily attributed to the interglacial interval of excavation."

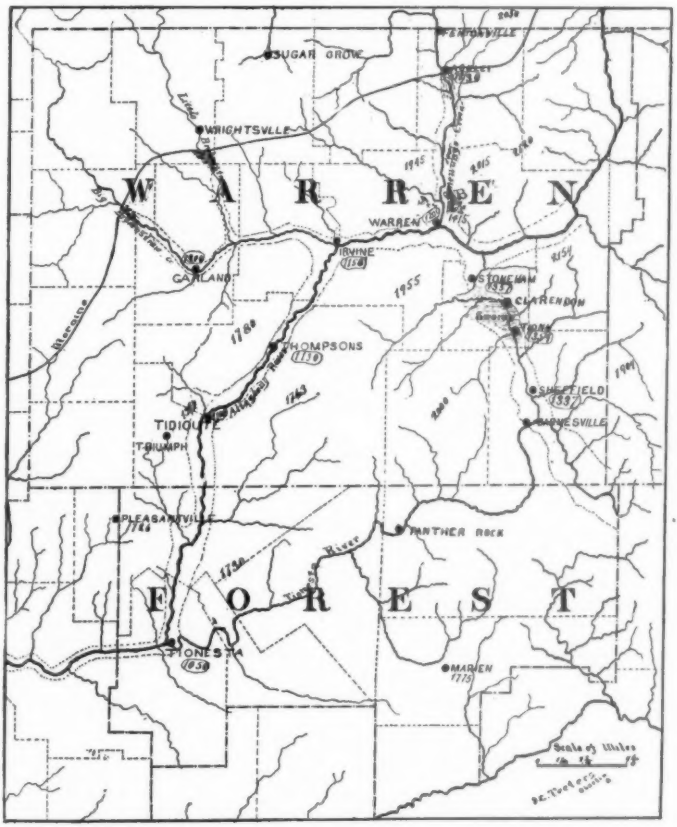
Before the publication, but subsequent to the writing, of this note by Professor Chamberlin, however, Mr. Leverett and I had together gone over a portion of the ground in the Allegheny River Valley most likely to yield definite results, including one of the most important points to which Professor Chamberlin had appealed in support of his theory, and brought to light facts which seem unequivocal in their interpretation. Upon the accompanying map is shown a portion of the Allegheny near Warren, Pa., where the Conewango joins the river to the north, and a short run comes in from the south which heads in a low pass separating it from a branch of the Tionesta River, which reaches the Allegheny fifty or sixty miles below.† The terminal moraine traced by Lewis and myself crosses the C newango at Ackley, about ten miles above Warren. The elevation of the Creek at Ackley is 1236 feet above tide. The

* See Professor Chamberlin's note upon the subject in the Journal of Geology, vol. i, p. 628, Sept.–Oct., 1893.

† Shows details in the Valley of the Allegheny in Warren and Forest counties, Pa. The broken line shows approximately the exterior margin of the rock shelves marking the Tertiary base-level of the stream. The figures along streams give the elevations above tide of the railroad stations which are usually but little above the flood plain.

moraine is about forty feet higher. The overwash terrace plane declines southward, so that at Warren it is but a little over 1200 feet above tide. The trough averages, I should say, about half a mile in width, and is bordered by hills to a height of about 2000 feet above tide, or from 700 to 800 feet above the present valley.

FIGURE 3.



Between the lower terrace referred to and the higher hills there are the remnants of a rock shelf which is about 200 feet above the present level of the Allegheny River, and as the Allegheny and Conewango are both partially filled with gravel, this shelf is about 250 feet above the rock bottom of these streams, and is covered to a depth of from twenty to fifty feet

with river gravel containing granitic and other Archæan pebbles from Canada, demonstrating it to be of Glacial age.

It had been supposed that these high level gravels were mere remnants upon the rock shelf, which had endured while the stream had eroded its rock trench to its present level. But evidence is now brought to light which completely excludes this hypothesis.

The new evidence discovered is twofold: First, about three-quarters of a mile northeast of Warren there is a solid bank of stratified gravel extending from the lower terrace of the Conewango up to an elevation of nearly 250 feet above the Allegheny river, or about 1400 feet A. T. and spreading out over a rock shelf to the north. This terrace having been resorted to for gravel at different levels its constitution is plainly shown

FIGURE 4.

almost from top to bottom. The gravel pit at the upper part contains great numbers of Archæan pebbles several inches in diameter, while that in the lower pit which extends back beneath the coarser material is mostly assorted sand and fine gravel of similar composition beautifully stratified. Only one explanation of this is possible, namely, that the rock erosion in this valley had been nearly, if not quite, completed before the deposition of the high level gravels. Upon this special point of the extent of preglacial erosion at Warren Mr. Leverett and I are agreed, except possibly as to the erosion of the lower 50 feet in the rocky gorge immediately beneath the stream. The positive evidence of the gravel bank described covers only the erosion down to the bottom of the first terrace; but the remaining erosion in the rock is relatively too small seriously to affect the discussion.

The second line of evidence is found on the head waters of the Tionesta at and below Clarendon (see Fig. 3). Mr. Leverett had on a previous day visited the place and found evidence that this valley contains a glacial overwash at Clarendon. Some years before Mr. P. F. Carll, of the Pennsylvania Geological Survey, had noted, and I had also had my attention called by Mr. H. H. Cummings, of Tidioute, to the width of

the valley at and south of Clarendon, and to the singular course of the Tionesta river in flowing away from the broad valley at Barnesville through a very narrow one at right angles to it. But in a hasty trip to the region no definite results had been attained. Upon returning, however, with Mr. Leverett it was found that the whole appearance indicates that the south branch of the Tionesta formerly flowed along a valley occupied by the north branch, past Clarendon, through a buried channel to the Allegheny. Positive evidence of this fact also was furnished by Mr. D. E. Waugeman, a dealer in materials for well drilling, who was cognizant of the history of nearly all the wells sunk for oil in that vicinity. According to his testimony (and he furnished the materials for many of them) several of the wells sunk near the station at Clarendon were driven through gravel and sand from 160–171 feet before striking rock. This would carry the depth of the buried channel nearly to the level of the present bottom of the Allegheny, five miles to the north. A well was subsequently reported to Mr. Leverett, which is situated on a terrace two miles south of Clarendon, to have penetrated 263 feet of drift, giving the rock floor there an altitude of but 1167 feet A. T. or but 73 feet above the lowest known point in the rock floor at Warren and only 20 feet above the undisputed limit of preglacial erosion there. It was noted further that in the vicinity of the place of reversal below Barnesville the small side valleys are excavated broadly to such a depth as to show (as Mr. Leverett and myself agreed) that erosion there, like that at Warren, had been carried nearly to its present depth in preglacial times, and that the col may not have been materially lowered by the reversal because of the excessive amount of filling north of it (see Fig. 3). We were much impressed by the great amount of drift on the Clarendon watershed, as well as by the fact that Archæan pebbles are numerous. The level of the watershed, near Clarendon station, is 235 feet above the river at Warren, the river level being about 1160 feet A. T. The gravel terrace rises, as determined by Mr. Leverett's observations, 105 feet higher, or 340 feet above the Allegheny, which makes it about 100 feet higher than the terrace just described on the Conewango east of Warren, and fully 200 feet above the rock floor of the Tionesta, at the place of reversal near Barnesville twelve miles to the south, and more than 300 feet above the rock floor in the boring two miles south of Clarendon. This terrace in the valley of the Tionesta is also exceedingly well developed two miles south of Clarendon just west of Tiona. We did not find any Canadian pebbles south of Tiona but there was much gravel in the valley, especially where the two branches of the Tionesta at Barnesville join to enter the gorge

down which the water flows for the rest of its course to the Allegheny, and Mr. Leverett subsequently found that the Tionesta contains Canadian rocks in its gravels at Newtown Mills, only a few miles above the mouth of the stream.

This evidence is of itself conclusive upon the main point in question. The accumulation of the oldest Glacial material took place subsequent to the erosion of the rock valleys of the region. Whether these Glacial deposits in the upper part of Tionesta valley imply that the Glacial ice actually crossed the Allegheny at this point, or whether the deposits can all be accounted for as overwash gravel from the ice border north of the Allegheny is immaterial to our main discussion, though it would seem pretty certain that the gorge of the Tionesta from Barnesville down was of preglacial origin. For, in company with Mr. D. C. Baldwin, I followed it through its whole course, and found it everywhere exhibiting signs of great age. The tributary valleys are well developed and eroded to the general level of the main stream. The stream is, however, characterized by a remarkable absence of extensive gravel deposits which I expected to find upon the theory of its having been so important a line of Glacial drainage; but this is probably due to the short continuance of the time of its occupation by Glacial drainage. The only extensive gravel deposit noticed was a deserted channel at Kellettsville, a little below Panther Rock, near where Salmon Creek enters the main stream. The deserted channel was, on the north side, fifty feet above the present river, and separated from it by a narrow ridge 130 feet above the river. Both the old channel and the ridge were covered to a depth of about twenty feet with river gravel, but I failed to discover any Archæan pebbles.

The significance of the facts here brought to light cannot be evaded by the discussion of minor questions relating to the subject. Mr. Carll has indeed adduced many considerations going to show that the former drainage of the upper Allegheny Valley went northward through the Conewango to Lake Erie. The evidence of this being that the rock bottom of the Conewango at the New York State line is, according to Carll, 136 feet lower than the rock bottom of the Allegheny at Great Bend, a few miles east of Warren. It is not necessary to discuss this theory here further than to say that Mr. Carll's facts do not seem to prove the northward flow of this drainage so clearly as I formerly supposed they did; for Mr. Carll's reasoning has failed to take into account two considerations which may essentially modify the inferences from the facts.

In the first place, no one has been able fully to eliminate from the problem the effects of orographic changes of level upon the present attitude of the rock bottoms, to which Professor

I. C. White has specially called attention.* In the second place, I have been led to reflect much for some years past upon another cause which may produce great irregularities in the depth of the rock bottom of river gorges, namely, the effect of the plunging force of a cataract in hollowing out the gorge at its foot to a depth much below the general level. The extent of this process will depend partly upon the character of the underlying rock, and partly upon the conditions which determine the extent of the plunge of the water over the cataract. It is well known that the plunge of the water over the Niagara escarpment has scooped out a channel to a depth of 200 feet or more below the level of the stream north of the falls. While studying the gorge of Snake River above the Lower Shoshone Falls in Idaho three years ago, I was struck with a similar phenomenon. The water is but a few feet deep over the crest of the falls; but, less than half a mile above the falls, the depth becomes 100 feet or more, and so continues for some distance. The most natural explanation of this would seem to be that during the recession of the upper falls there were conditions which favored deep erosion much more at certain places than at others. These conditions may have been those which should determine that at certain places the fall was mainly over rapids, and at other places in a perpendicular plunge. The varying hardness of the strata underneath may also have combined to produce the result. It has seemed to me that some such combination of causes as this may account for many, if not all, the facts which are appealed to in the upper Ohio Valley in proof of the former northward flow of its drainage.

But the settlement of this point is immaterial to the question in hand. The extent of the preglacial erosion now demonstrated to have taken place in the Allegheny Valley at Warren is so great that it carries with it, by natural inference, a similar extent of preglacial erosion all down the Ohio and in its tributaries. The erosion at Clark's Run, in the valley of the Beaver, which I have already described, is in accord with the facts concerning the Allegheny near Warren. In examining the Allegheny River from Warren down to Pittsburgh, although I did not find any other facts which are so unequivocal in their significance as these are; yet I did find much which confirms the view, and so far as I can see there is nothing which can be adduced as strongly favoring the other view.

The 200-foot rock shelf reappears at frequent intervals all the way down the Allegheny to its junction with the Ohio, and down the Ohio as far as Wheeling certainly. It varies

* This Journal, for 1884, p. 149.

considerably in width, depending upon the ability of the rocks to resist or facilitate erosion; while sometimes the shelf is wholly wanting for a considerable distance where the river passes through areas of more uniform and compact strata. But almost everywhere down to the junction of the Big Beaver with the Ohio this 200-foot rock shelf is covered with glacial gravel to a depth of from twenty to sixty feet and sometimes for a width of a half mile. The extent of the deposits of this high-level terrace has not heretofore been duly understood or appreciated. The portions heretofore described at Bellevue on the Ohio, just below Pittsburgh, and that at Parker's Landing, on the Allegheny, can be duplicated at brief intervals throughout the entire length of the valley from the mouth of the Conewango to the mouth of the Big Beaver. The deposits are found almost continuously upon the east side of the Ohio River, from the mouth of the Big Beaver to Pittsburgh, while in Allegheny City remnants of the gravel remain upon the summit of Monument Hill, which rises in the center of the city to the level of the rock terrace, but is separated from it by a quarter of a mile or more of a partially buried old channel of the river. Under guidance of Professor Jillson, who will soon publish a detailed paper upon the subject, I traced this high gravel terrace for some twenty miles up the Allegheny River. It is developed in specially good degree on both sides of the river above Allegheny City and Pittsburgh, and farther up near Verona, upon the south side of the river, and on the north side opposite Parnassus, and again from Tarentum for several miles upon the same side nearly to Freeport. In all these places the accumulation of gravel upon the rock shelf is from twenty to sixty feet in depth, and frequently is as much as a half a mile wide. The material is much of it fine and often well stratified, but contains numerous water-worn Canadian pebbles and occasionally, enclosed in the fine material, angular fragments of granite, gneiss, or sandstone two or three feet in diameter, indicating ice-laden currents. At East Liberty, in the upper part of Pittsburgh, the deposit from the Allegheny River crowds over upon a limited amount of river pebbles which had been distributed along the deserted bed of the Monongahela which is now followed by the Pennsylvania Railroad in getting out of the city, and which is about the same height as the rock shelf referred to. Farther up the Allegheny River, in company with Mr. D. C. Baldwin, I have examined similar deposits along this rock shelf at Ford City, Kitanning, Red Bank, East Brady, Parker's Landing, Kenerdell (formerly Scrub Grass), and many other places. Of these I will now speak further only concerning Kenerdell and Parker's Landing.

Opposite Parker City there occurs the deserted river bed so fully described by Mr. Chance,* and whose descriptions are reproduced by Professor Chamberlin† to controvert my views concerning the preglacial origin of the rocky gorge of the river at this point. But Mr. Baldwin and I discovered some things not heretofore noticed which in themselves strongly confirm my previous views concerning the preglacial date of the rocky erosion. The details can be clearly and briefly stated in connection with the accompanying map (slightly modified from that of Mr. Chance.‡ The elevation of the Allegheny River at low water is here 840 feet, and the width of the rocky gorge is 1500 feet. The rock bottom is fifty feet lower. The summit of the gravel upon the rock shelf which we have been considering is 250 feet above low water, or 1090 feet above tide. Upon the east side of the river there is a deserted rock channel in the shape of an ox-bow extending out about a mile and a half from the main stream, but at an elevation of about 200 feet above it. This is partially filled, to a depth of thirty or forty feet, with river gravel of Glacial origin. Mr. Chance and Prof. Chamberlin supposed that this deposition took place previous to the lowering of the rock gorge from the level of the ox-bow to the present rock bottom of the river, a perpendicular distance of 250 feet. But the additional facts which I now have to present will, even in themselves I think, disprove this hypothesis, and show that the existing rock erosion of the main channel had taken place, to a large extent at least, before the deposition of Glacial gravel in the ox-bow.

That the ox-bow was at an early period eroded by the river appoximately to its level at the point farthest away from the present stream cannot well be doubted; but there is evidence also that after its desertion by the main stream the small streams occupying the two prongs of the bow had accomplished a good deal of erosion before the deposition of the gravel; for there is a considerable slope of the rock bottoms of these small tributaries in their progress towards the river, and it is evident that their beds had finally assumed the shape which results from the erosion of such small streams rather than from the passage of a great river. This would go to prove that the undercutting of the neck had been fully accomplished long before the partial filling of the ox-bow with gravel. Furthermore, the upper prong of the bow is filled in with gravel around to its farthest extremity at A; while the lower prong of the bow is filled in with gravel only a short distance, namely,

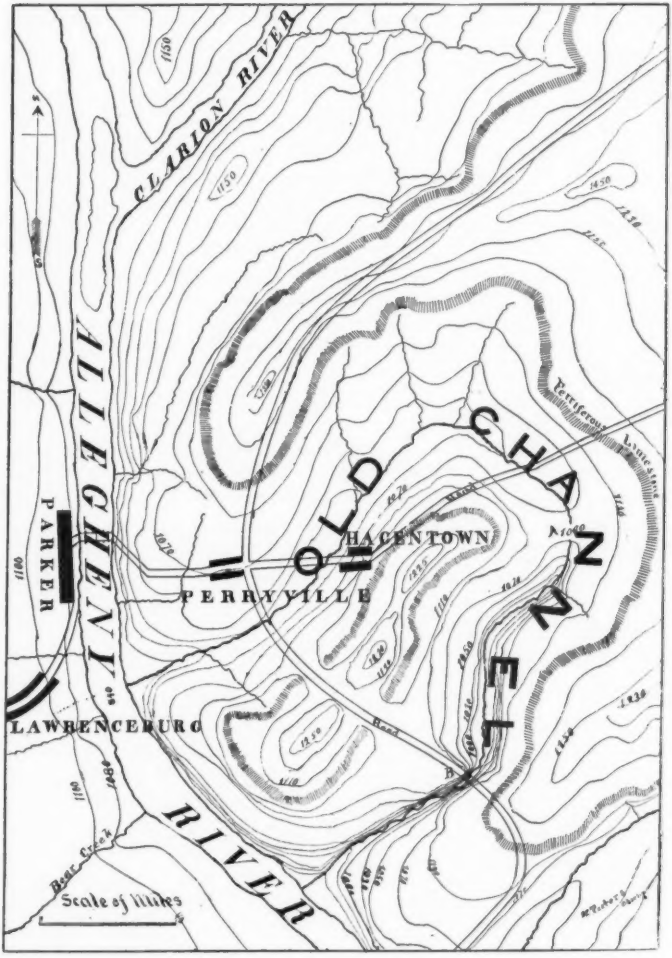
* Second Geol. Surv. Pa., VV, 1880, pp. 17–20.

† Introd. Bull. U. S. Geol. Surv. No. 58, p. 30.

‡ Map of old channel at Parker partially filled with high-level Glacial gravel. See section on lower right hand corner of Fig. 1.

to B. Between A and B the lower prong is entirely free from foreign gravel for a distance of half a mile or more; but the valley of the prong through this distance is broad at the top and V-shaped, and is distinctly constricted near B by the gravel deposits. This portion of the valley could not have been hollowed out of a gravel deposit such as exists upon the northern prong, and nothing of the sort exists on the north side.

FIGURE 5.



Clearly the explanation is that before the deposition of the gravel in the ox-bow the rock erosion had proceeded till it had produced essentially the present topographical conditions. The gorge of the Allegheny was then refilled with Glacial gravel till it reached the summit of the 1100-foot terrace upon the western side, and partially filled in the ox-bow across the outlet of both its prongs. Naturally the work proceeded fastest in the upper prong, and the terrace was gradually built out till it reached the point A. Naturally, also, there would be no such extensive pushing of material up the lower prong; so that we find across it simply a gravel terrace corresponding to other terraces upon that side of the river. The continuance of the Gacial floods at that level was not sufficiently long to permit the deposition which had taken place in the upper prong to extend around the whole circuit of the loop. Evidently the depositing Glacial flood after attaining its maximum height retreated with comparative rapidity,—a rapidity which is not at all consonant with the theory that it was compelled to lower its bed through a rock bottom; nor does the general appearance of the high-level gravel deposit, either here or elsewhere, indicate such an enormous age as Professor Chamberlin's theory would imply. There is everywhere against this theory the relatively small amount of erosion which had taken place in the gravel since the deposition.

The second case upon which I will stop briefly to comment is at Kennerdell, which is situated upon a point of a long ox-bow occupied by the present river. Here the gravel with Glacial pebbles constitutes a continuous blanket up the slope from the river to a height of something over 300 feet. Up both of the roads branching off from the station, and reaching the summit on either side of the ox-bow, this deposit of gravel is continuous, and contains Archæan pebbles nearly up to the height above mentioned. The theory that this blanket of gravel (how thick it is I did not have time to ascertain, for the rock nowhere appeared along the roads) is simply a remnant that has survived the long period during which the whole rock gorge was eroded, and which has gradually slid down from the summit or been re-deposited as the shelf was undercut, I think few people who examine it will entertain. On the other hand, it is not difficult to understand how it might be left in the process of a re-erosion of the trough after it had been filled with loose material.

The conclusion to which all these facts point with convincing force is that, after a long period of base-levelling in the Tertiary era, during which the 200-foot rock shelves formed a portion of the bottom of the stream, there came on a continental elevation which permitted the streams rapidly to cut narrow,

gorge-like channels down through the rock to a depth of 250 or 300 feet below their former level. Simultaneously with the culmination of this uplift, and with the conclusion of this long work of erosion, Canadian ice reached the headwaters of the Allegheny, and a work of deposition began which proceeded as long as the ice continued to advance, and probably for some time after it began to retreat. The upper part of the Allegheny River became filled with debris up to the summit of the high-level bowldery terrace extending over the rock shelves, and the sedimentation gradually advanced along the narrow trough until it was entirely filled as far down as the mouth of the Beaver, and perhaps to Wheeling, and possibly still farther. Subsequently the larger part of this material was eroded, and carried down into the Mississippi Valley. If there were two distinct Glacial epochs, the minimum measure of time between them is not that of the rock erosion of the gorge, but the erosion of this loose material.

Now in studying this problem we cannot wholly ignore the Cincinnati ice-dam, even though that hypothesis may have been somewhat overworked in former years. I need not repeat the positive evidence of this dam elsewhere presented* any farther than to say that the arguments adduced by Professor James,† proving that the preglacial course of the Ohio River was around by Hamilton, and thence down the Great Miami,‡ adds immensely to the significance of its obstruction during the Glacial period. The existence of such an obstruction must have greatly facilitated the silting up of the gorges of the upper Ohio Valley, and have had a great influence in modifying the character of the deposits. An immense amount of fine material which otherwise must immediately have been swept onwards to the Mississippi would settle in the slack water depths of this narrow winding lake and serve as the basis to support the coarser deposits that were brought down over them. Some positive evidence upon this point has been furnished me by Mr. R. C. Hice. In digging for the abutments of the bridge across the Big Beaver at Ellwood,§ just above Homewood, the workmen penetrated sixty or more feet below the present bottom of the river, and found it filled uniformly with a very fine deposit such as could settle only in the stillest of water. In the portions of the Ohio Valley nearer Cincinnati the ice dam removes the necessity of supposing so exten-

* See especially Bulletin of U. S. Geol. Sur., No. 58; Ice Age of North America, pp. 326–350.

† See Journal of the Cincinnati Society of Natural History, July–October, 1888, pp. 96–101; also American Geologist, 1893, pp. 199–202.

‡ See map in Fig. 1.

§ See map, Fig. 2.

sive a filling up of the trough as we find above the mouth of the Big Beaver.

The facts brought to light concerning the extensive filling up of the trough of the Allegheny and upper Ohio Rivers must modify to some extent previous theories concerning the still water deposits in the Monongahela River. That the deposits described by Professor White at Morgantown, W. Va., took place in still water, which was produced by some extraordinary obstruction to the drainage after the main part of the rocky erosion had taken place is scarcely capable of being questioned by one who has carefully examined them in detail. This Professor Chamberlin and Mr. Gilbert were not able to do, since their visit to the region was hasty, and they did not have the privilege of the guidance of Professor White, who was absent from home at the time. I have had the privilege of going over much of the ground with Professor White, and need only to reiterate and emphasize the most significant of the facts which he has elsewhere so fully stated. There are at Morgantown both in the immediate vicinity of the Monongahela and at the Flats (a mile or more back from the river, along one of the small tributaries of the main stream) deposits of clay seventy feet deep containing at all levels the impress of the leaves of existing species of trees and fragments of wood in a good state of preservation. I can see no way in which such depths of clay and gravel could accumulate in the ordinary process of the rock erosion of a stream. There must have been some check to the processes of erosion during which this extensive silting took place. Professor White is inclined to believe that orographic changes may have played more of a part in producing slack drainage in the streams on both sides of the Allegheny Mountains than he at one time thought. The slightly higher level (about 100) feet of these deposits in the Upper Monongahela also compels us to suppose some slight orographic changes of level if the Cincinnati ice dam alone is depended upon for the obstruction.

In the light of the present discussion it will be seen that a supplementary cause of great significance may now be taken into consideration. The action of the Allegheny River when swollen with its Glacial floods and burdened with its vast loads of Glacial debris would dam up the mouth of the Monongahela by the same accumulations which filled its own channel. As we have seen, these accumulations rose at Pittsburg to a height of about 300 feet above the present water level, or of 1,000 feet above tide level. As the conditions were so much more favorable for the sedimentation of the Allegheny during the reign of the Glacial period than for filling up the trough of the Monongahela, such an obstruction was inevitable. Thus also

the accumulations in the Monongahela attributable to this epoch were chiefly of fine material and near the mouths of tributary streams. It is not necessary to suppose that the Monongahela was filled throughout its entire length, as was the case with the Allegheny. Professor Jillson reports that the 200-foot rock shelf along the Monongahela near Pittsburgh is almost wholly free from gravel, and has but a foot or two of soil for a covering.

A similar damming up of rivers by tributaries has been frequently noted. Mr. G. M. Dawson shows that the deposits of Dead Man's Creek opposite to its mouth have filled up Thompson's River (the principal tributary of Fraser's River in British Columbia) a depth of 450 feet making Kamloop's Lake, a body of water eighteen miles long and nearly two miles wide.* General Warren has detailed similar evidence respecting the Mississippi. Lake Pepin, for example, is made by a delta of Chippewa River which is pushed across the Mississippi just above Waukesha, Minn.†

Thus the investigations of the past year would seem to remove from the problem the most considerable and definite factor used by Professor Chamberlin in estimating interglacial time. What he supposed was *inter*glacial was *pre*glacial, as others had all along contended. We shall therefore be the more ready to accept similar conclusions regarding the date of the extensive rock erosion in the Delaware and Lehigh river valleys, which Professor Chamberlin would also make interglacial.

Preglacial Erosion in the Delaware Valley.

In the summer of 1892 Professor A. A. Wright and myself devoted some time to an attempt to determine the southern limit of the fringe, or "attenuated border" of glacial deposits in the Delaware Valley; for, that there was such a fringe in advance of the moraine was recognized many years ago by Professor Cook and by Professor Lewis and myself; while Professor Salisbury had published in 1891 what seemed to be a much exaggerated view of its extent. The results of our work were summarized in my previous paper upon this subject in this Journal (see pp. 364–367, Nov. 1892). In the time then at our command we only succeeded in determining one fixed point on the southern border, namely, on the summit of the Musconnetcong Mountain, about five miles east of Riegelsville, leaving the rest of the line professedly undetermined.‡

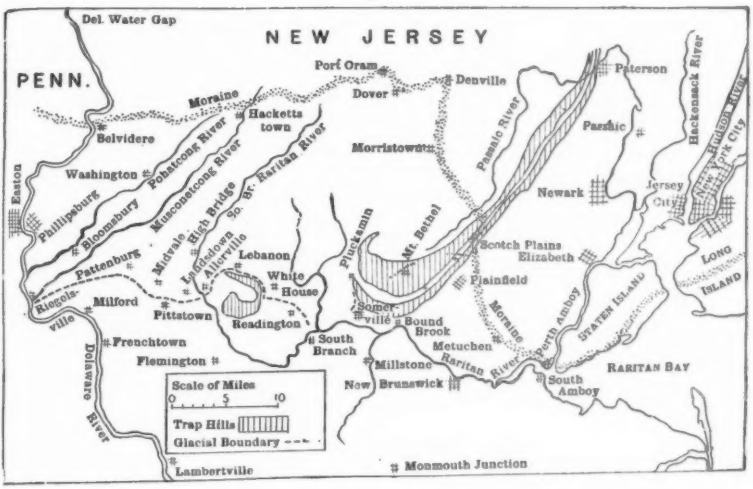
* Geol. Survey of Canada, Report of Progress for 1877–78, p. 17.

† This Journal for 1878, p. 420.

‡ I have presented this evidence more fully in a paper before the Philadelphia Academy of Sciences, published in their Proceedings for 1892, pp. 469–484.

During the summer of 1893, Professor Wright and myself returned to this field, and the results of our work were presented by him to the Geological Society of America at its meeting last August, and are published in their proceedings (vol. v, pp. 7–13). The accompanying map, prepared by Pro-

Fig. 6.



fessor Wright, shows the limits of the Glacial fringe in New Jersey as now determined by us and its general relation to the moraine. It includes the deposits at High Bridge and Pattenburg, concerning whose Glacial character I expressed doubts a year ago. Further search, however revealed outside of these two localities the evidence which we had considered lacking. In the eastern part of the State the level of the land is so little above tide that it is difficult to distinguish between the direct deposits of the glacier and those which have been distributed by water. But from the central part of the State westward I think there will be no occasion materially to modify our line. Meanwhile Professor E. H. Williams, Jr., has been making a careful survey of the southern boundary of the Glacial deposits in the Lehigh Valley, and finds them continuing across the Delaware River at Riegelsville, (where it should be said Mr. C. Laubach, a local observer, has for many years been correctly insisting that direct Glacial deposits existed), and extending over South Mountain, to the Saucon Valley near its head, and thence westward several miles south of Bethlehem, into the limestone valley which runs southward from the Lehigh at Allentown, and joins the Schuylkill above Reading. In this

valley the ice extended to Topton, which is the water shed between the two above-mentioned rivers; thus bringing to light an important and hitherto unsuspected temporary line of Glacial drainage into the Schuylkill River.*

One significant observation of Professor Williams has a specially important bearing upon the date of this earlier glaciation. Just south of Bethlehem, at the site of the new reservoir, on the north flank of South Mountain, the gneiss is very deeply decomposed, showing an extremely long exposure to disintegrating agencies. But upon the summit of the mountain, where there are evidences of glaciation, the decomposition of the gneiss extends only to a few inches below the surface. Professor Williams' interpretation of this would unquestionably seem to be correct, namely, that the twenty feet of decomposed gneiss upon the north side represents preglacial work, where the material had, in some way, been protected from erosion during the ice-movement, while the few inches of decomposition upon the summit of the mountain represents the work since the deposition of the fringe; material loosened by preglacial decomposition having been removed by the ice from the summit.

The thinness and irregularity of the deposits over the area which we have denominated "the fringe" in New Jersey and Eastern Pennsylvania are supposed by Professor Salisbury† to be due to the action of the long period of erosion to which it has been subjected. This seems extremely questionable. At any rate, there does not appear to be any definite evidence that this is the true explanation. On the contrary, it is more likely that the original deposition near the margin and for some distance back was slight and irregular, owing to the comparatively brief stay of the ice near the margin of maximum extension and to the small amount of motion which characterized the extreme border.‡ This view is confirmed, also, by the fact that Mr. Leverett in his careful study of the deposits in Southern Ohio is of the opinion that there the attenuation of the border deposits is due "more largely to original deposition, than to subsequent erosion."§

With regard to the age of the Philadelphia brick clays and red gravel in the Delaware Valley, the evidence seems to point more and more clearly to a closer continuity with the Trenton gravels in their deposition than Professor Chamberlin supposes.

* Williams, Proc. of the Geol. Soc. Am., vol. v, pp 13–15. See further convincing facts in the short paper of Professor Williams in this Journal for Jan., 1894, pp. 33–36.

† Annual Report of New Jersey, for 1892, p. 64.

‡ See diagram. Fig. 7, and explanation by Mr. Warren Upham on page 185.

§ See Glacial Succession in Ohio, Journ. of Geol., vol. i, p. 132.

In Professor Salisbury's last Report upon the surface geology of New Jersey, he arrives at nearly the same conclusion with Professor Lewis, namely, that there was during the earlier glaciation a subsidence of the eastern coast in that region to the extent of at least 130 feet. In an examination which I made last summer, in company with Mr. Ernest Volk, of the gravel terraces west of Trenton, N. J., and extending from Fallsington to Yardleyville, Pa., the facts elicited seem to show that the deposition was continuous and comparatively rapid from the gravels at a level of about 170 feet near Yardleyville down to the valley at Fallsington, where the level of the terrace is but slightly above that of Trenton. The gravel rests upon the gentle slope in a nearly continuous blanket, and not in the irregular manner which must have been the case if it had been working down from a higher elevation over a slope that was gradually formed by the lowering of a broad valley through undercutting of the solid rock.

The evidence brought to light during the past year thus seems in the clearest manner to remove many of the arguments which have been adduced to prove an extremely long interglacial episode and the consequent discontinuity of the epochs. Several specially important papers, however, have been presented during the year aiming to show that the lapse of time between the maximum of glaciation and the formation of Professor Chamberlin's "terminal moraine of the Second Glacial epoch" is much longer than the period which extends from the formation of the second moraine to the present. Mr. Leverett (the value of whose extensive observations is becoming more and more apparent), in a paper before the Geological Society of America in August last, adduced much cogent evidence to show that the present valley of Rock River in Illinois is different from the preglacial valley, and that where it now runs through the area of the older drift the erosion is so great that it calls for seven or eight times as long a period as that demanded by the postglacial erosion of the Niagara River or by the postglacial work of the Mississippi below the Falls of St. Anthony. Mr. Oscar H. Hershey,* also, adduces similar evidence from the area of the older drift occupied by several small tributaries of Rock River in Stevenson County, Illinois. The minimum age of those portions of the gorges of these streams which have been formed since the occupation of the region by ice, is estimated by Mr. Hershey to be 50,000 years. Mr. Leverett also adduces the great amount of erosion in the till which covers Sangamon County and the region farther south in Illinois, as compared with that north and east, to prove that the older drift is several times older than the newer.

* Am. Geol., vol. xii, p. 314 seq.

In proof of the same calculation Mr. Leverett also adduces the fact that in Southern Ohio the till is oxidized to a yellow color to a depth of about twenty feet, below which it is unoxidized and blue.*

These moderate conclusions of the date of the period of maximum glaciation are so strikingly in contrast with those which have been adduced from Mr. Croll's astronomical theory, and with those which would be necessary if Professor Chamberlin's theory of the interglacial origin of the rock gorge of the Ohio River had been true, that it is hardly worth while to make any issue with regard to them. At the same time it is proper to note, first, that, in streams which are flowing outward from the glaciated area, there is considerable danger of confounding preglacial with postglacial erosion; and in the second place, that we are bound to keep in mind that when these streams were first pushed out of their original channels by the ice the present channels probably became lines of Glacial drainage, in which the supply of water and other conditions may have favored very rapid work. And, thirdly, apropos of Mr. Leverett's observation upon the oxidation of the till in Southern Ohio, I would say that certain facts which have come under my own observation during the past summer would seem to indicate that local considerations which we do not fully understand may so far control the rate of oxidation as seriously to interfere with calculations from that factor alone.

Oberlin lies in the watershed of Lake Erie in the area of later glaciation north of Mr. Leverett's twelfth moraine. During the past season miles of trenches have been dug in providing sewerage for the town, and the facts have been carefully collected by Mr. Lynde Jones, and have been under constant observation by Professor A. A. Wright and myself. Mr. Jones will soon publish his results. But one fact only is necessary for my present purpose. Everywhere the yellow till extends down to a depth of several feet, ranging from six to fourteen, where it is underlaid by blue till. It would thus appear that in the compact deposit in the northern part of Ohio, in one place at least, the oxidation is from one-third to two-thirds as deep as that which is reported by Mr. Leverett in the oldest drift in the southern part of the State.

Mr. McGee's latest Views.

During the year, also, Mr. W. J. McGee, formerly of the United States Geological Survey, has published a highly illustrated and elaborate report upon "The Pleistocene History of Northeastern Iowa," which brings to light many suggestive

*See the Glacial Succession in Ohio, Journ. Geol., vol. i, p. 132.

facts bearing upon the question in hand. Notwithstanding the general excellence of the report, we are not sure that we have been able altogether to ascertain the personal equation of the writer; for in many places it is evident that slenderly supported inferences are stated with such an unwarranted degree of confidence as is calculated seriously to mislead the uninformed reader. This is specially the case in the part which he has assigned to the Pleistocene water bodies. Repeatedly in his maps he covers the driftless area of Wisconsin with a body of water produced by the damming up of the Mississippi through the junction of the lobes of ice which came down from either side. This he has named Lake Hennepin. I have not much personal familiarity with the region; but, judging from the explicit reports upon it by Professors Chamberlin and Salisbury, they would seem to be correct in discrediting the existence of any such body of water. I am more familiar with the region in Indiana between the forks of the White River, just south of the moraine—a region which I explored somewhat carefully ten years ago. This is the highest land in the State, running up in one place to an elevation of 1147 feet above tide, and the whole country to the south of it was open during the glacial period.* In short it is an impossible position for a Glacial lake. Yet Mr. McGee has it covered with a Pleistocene body of water.

Nevertheless, this tendency to theorizing independent of the facts may not be allowed to discount the great body of Mr. McGee's observations which bring to light several very important things. We note in the first place, that, while the sixteen thousand square miles in Northeastern Iowa upon which he reports lies entirely outside of what Professor Chamberlin had reckoned as "the terminal moraine of the second Glacial epoch," yet Mr. McGee insists that the area is covered by the remains of two Glacial epochs, separated by an interglacial period, which is rather indefinitely reckoned as from 28 to 280 times as long as the period of written history, that is from 200,000 to 2,000,000 years in extent, if by written history he includes the writings upon the monuments in Egypt and Babylonia.

Secondly, the principal basis of this inference is the existence of a forest bed over a portion of the area near the margin, and a marked difference between the character of the upper and lower tills.

But, thirdly, the character of the vegetal deposits does not indicate as warm a climate as that which now characterizes the region; but, like those in Southern Ohio, which Professor Orton and Mr. Leverett have described, the interglacial trees

* See map, Fig. 1.

are mostly coniferous, and such as may well grow upon the very border of an ice-sheet.

Fourthly, though supposed to be separated by such an enormous interval, these two ice-invasions very nearly duplicated each other; the second extending down very near to the margin of the first; so that while the first covered an area of 13,000 square miles, the second covered an area of 12,000 square miles.

Fifthly, Mr. McGee's interpretation of the blue till at the bottom is exactly the reverse of that put forth by Mr. Leverett and most observers. The upper till in this area is yellow, while the lower is blue. Usually it has been thought that the yellow till measured the extent of the oxidation from the surface down. Of course, then, the older till should have been completely oxidized, and yet throughout this part of Iowa it has the blue color of the unoxidized till. Mr. McGee believes—on what basis except purely theoretical it is difficult to see—that it has indeed all been oxidized, but was then deoxidized through the influence of the overlying forest bed.

Altogether this report of Mr. McGee does not seem likely to lend any solid support to the theory of an extremely long interglacial epoch which he has so confidently espoused.

Summary.

In giving a brief summary of the course of events connected with the Glacial period, it will come in the way to state more fully than has heretofore been done how those who question the long interglacial epoch can account for what has been called the moraine of the second Glacial epoch, and for the river terraces which everywhere, east of the Mississippi River, head near the moraine.

So far as known, the following scheme would seem most naturally to comprehend all the facts relating to the Glacial period in America:—

1st. The earlier portions of the Tertiary period were characterized, throughout all the northern hemisphere, by low altitude of land and a warm temperature even in close proximity to the pole.

2d. A period of slow continental elevation of the regions which are now covered by Glacial drift, extending through some hundreds of thousands of years, was in progress late in the Pliocene epoch. During this stage of events the fiords which characterize the northern portions of both Europe and America, and the extensive rock gorges, like those of the upper Ohio River and its tributaries, were eroded.

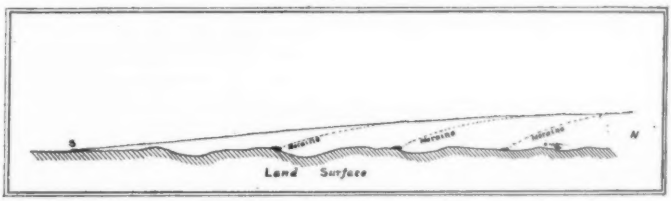
3d. Contemporaneously with this continental elevation at its maximum stage, and chiefly as a consequence of it, Glacial conditions characterized all the higher latitudes of North America and western Europe. In Eastern North America the center of

Glacial radiation was in the vicinity of James Bay. A land elevation of three or four thousand feet would perhaps have been sufficient to produce the Glacial conditions; but the accumulation of Glacial ice would eventually raise the surface several thousand feet higher.

4th. Before the climax of the Glacial period, and perhaps in consequence of its burden of ice, the glaciated area began to sink until the land was, north of the Great Lakes at any rate, several hundred feet, at least, lower than it now is. But for some time after the beginning of the subsidence of the land the rate of accumulation of ice would be greater than that of the subsidence; so that the general level of the glacier continued to rise. Thus the maximum extension of the ice-field was actually reached but a short time before the decline of the period set in.

5th. As suggested to me by Mr. Upham, "The frontal slope of the ice-surface was then less steep than when the warmer climate, bringing the end of the Glacial period, had begun to melt away the southern border. At the maximum of extent the slope may be thus represented:—terminating in a very

Fig. 7.



gentle declivity, allowing some transportation of bowlders to the boundary, but not generally so steep as to produce there any well-defined moraine. In the Glacial recession the warm sunshine and rains were especially efficient, on a belt a few miles or a few tens of miles wide adjoining the boundary, so that when any temporary colder series of years caused a halt or slight re-advance a moraine would be formed."

Lack of personal familiarity with glaciers of the first class has, I am persuaded, led Professor Chamberlin to misinterpret many of the facts connected with what he calls the moraine-headed terraces of the later Glacial epoch. As good an example as any is furnished on the Conewango Creek at Ackley, Pa.,* a region which I had repeatedly visited, both before and after my study of the Muir Glacier. Professor Chamberlin has much to say about the signs of vigorous ice-action in connection with the moraine of the second Glacial epoch, and of the moraine-headed terraces. The indications of this vigorous

* See map, Fig. 3.

action are not only the frequency of Glacial rock scorings to the north, but, among other things, the knobs and depressions in the moraine and in the head of the moraine terraces.

So far as the rock scoring and analogous phenomena are concerned, it is a matter of course that the agencies producing them increased in efficiency as you recede from the border; for all the ice which reached the border moved over the central area of glaciation together with all the ice that reached to any distance beyond the central area. The cup and saucer character of the deposits at the edge of the glacier where a moraine was formed, is probably due in considerable measure to the irregular melting away of ice which originally underlaid the deposit. The present level of the deposits is not by any means always the original level. At Ackley and for a short distance in the valley below, for instance, the ice was very likely originally at one time one or two thousand feet thick, and resting upon the rock bottom of the river trough. In the process of ablation, when the ice at the front had wasted to a thickness of 200 or 300 feet more or less, it was probably covered, as the front of the Malaspina and a portion of that of the Muir glacier are, with a vast amount of pebbles, sand, gravel, and clay which had gradually worked down upon it. In the place where the underlying ice was thickest, its melting away would let the superincumbent mass down to a lower level than that which rested upon a more permanent basis

This seems to be just what we have at Ackley. A terrace upon the east side two miles below Ackley, rises to a height of 150 feet above the flood-plain, and is level topped. On following it up the river, however, it soon ceases to be level topped, and exhibits knolls and saucer-shaped depressions characteristic of true morainic accumulations. At the same time it gradually falls to a lower level, so that at Ackley the moraine is not over forty or fifty feet above the flood plain, and north of Ackley these deposits in the valley give place to a long swampy stretch of country extending for several miles up the stream, and which is absolutely devoid of surface gravel. The explanation of this is that north of the portion of the terrace first mentioned the underlying ice in the valley was assuming greater and greater importance until above Ackley it reigned supreme. When at length it melted away, the gravel gradually and irregularly settled down to lower levels as the ice was thicker and thicker, until back of the moraine there was nothing but space left. If I mistake not, I have seen a similar process going on, on the east side of the Muir inlet, where the front of the ice rests upon the main land. If instead of debouching at its center into the tide water, this glacier was stretching out into a valley above tide with a distinct trough in the center, we

might easily have exactly the phenomena repeated which appear at Ackley and at various other places characterized by such moraine-headed terraces as were described by Professor Lewis and myself in 1881. Professor Chamberlin probably needs to revise his interpretation of these facts, in view of a wider knowledge of actual Glacial phenomena.*

6th. From the time the ice first entered the headwaters of the Allegheny, the Susquehanna, and the Delaware River, the silting up of their channels began. This was effected largely by means of the excessive amount of Glacial debris brought within reach of the streams. But during the earlier retreat of the ice-front from its maximum extent, the silting was facilitated by the differential northerly depression which existed. During a part of this time, also, it was facilitated in the Ohio Valley by the Glacial dam at Cincinnati.

7th. After some thousands of feet of ice had melted off, relieving the land from a large part of its burden, the re-elevation of the continent began; (and, as probably the most of the sedimentation of the preglacial river gorges had been effected during the earlier portion of this period of recession), there was then an indefinitely prolonged period of re-excavation by continuous torrents of comparatively clear water, facilitated in the Ohio Valley by the wearing away of the Cincinnati dam, which increased by so much the gradient of the stream.

8th. When equilibrium had been established again, the land was at about its present altitude, but was still covered to a considerable depth with ice north of the most prominent moraines. The great size of these moraines is partly due to the vast amount of englacial material held in the lower strata of the ice.

9th. The deposits of the so-called Champlain epoch near the margin of the glaciated area were considerably earlier in time than those which settled over the Champlain valley itself, since no deposits could take place there until the ice had retreated from the area; but these deposits are properly classed together as Champlain, since they belong to one epoch of general movement.

10th. So great a complication of causes was connected with the production of all the phenomena connected with the period that there were doubtless many oscillations of the ice-front both during the general advance and the general retreat of the ice-sheet. The extent and continuance of these oscillations is to be learned from study of the buried forests and vegetal deposits which lie between the earlier and later sheets of till, and by such instances of erosion as may be clearly proved to be interglacial. But there does not seem to be evidence of any oscillations of the front sufficient to break the proper continuity of the period.

* For an interesting discussion of the points here at issue, see Warren Upham, Bulletin of the Geol. Soc. of America, vol. v, pp. 71–86; 87–100 (Jan., 1894).

ART. XVIII.—*On the Chemical Composition of Chondrodite, Humite and Clinohumite;* by S. L. PENFIELD and W. T. H. HOWE.

Introduction.—These minerals, which are regarded collectively as the humite group, have been the subject of repeated crystallographic and chemical investigation. For our knowledge of their crystallization we are indebted to such careful and accurate observers as Haüy, Phillips, G. Rose, Lévy, Miller, Hausmann, Hessenberg, A. Scacchi, vom Rath, Nordenskiöld, Kokscharow, J. D. and E. S. Dana, C. Klein, Des Cloizeaux and Hj. Sjögren, whose names are familiar to all workers in crystallography and mineralogy. It is not the purpose of this article to take up the details of the crystallization of these minerals or to review the progressive steps by means of which we have derived our present knowledge of their highly modified and complicated crystals, but reference can be made to the excellent historical sketch in a recent number of Dr. Hintze's Mineralogy, page 370. In the description of the crystals that were examined during the course of our investigation we shall use essentially the same system of lettering and of crystal notation adopted by A. Scacchi* and E. S. Dana.†

In the humite group three distinct species are at present recognized, each characterized by the occurrence of certain forms which are not found on the others and having the following axial relations:

Chondrodite, Monoclinic, $a:b:c = 1{\cdot}08630:1:3{\cdot}14472\ \beta = 90$‡
Humite, Orthorhombic, $a:b:c = 1{\cdot}08021:1:4{\cdot}40334\ \beta = 90$§
Clinohumite, Monoclinic, $a:b:c = 1{\cdot}08028:1:5{\cdot}65883\ \beta = 90$‖

In the above the a axes are practically alike, while, as shown by Scacchi and vom Rath, a simple relation exists between the vertical axes, that of chondrodite being $\frac{2}{3}$ths and that of humite $\frac{1}{3}$ths the length of the clinohumite axis. These relations are shown in the following table, to which the axial ratio of chrysolite, a closely related mineral, has also been added.

Chondrodite	$a : b : \frac{2}{3}c = 1{\cdot}08630 : 1 : 0{\cdot}62894$
Humite	$a : b : \frac{1}{3}c = 1{\cdot}08021 : 1 : 0{\cdot}62905$
Clinohumite	$a : b : \frac{1}{3}c = 1{\cdot}08028 : 1 : 0{\cdot}62876$
Chrysolite	$b : 2a : \quad c = 1{\cdot}0735 \ : 1 : 0{\cdot}6296$

* Pogg. Ann, Erg. B., iii, p. 161, 1851.
† Mineralogy, Sixth Edition, p. 535. Trans. Conn Acad., iii, p. 67.
‡ E. S. Dana, loc. cit.
§ A. Scacchi, loc. cit.
‖ vom Rath, Pogg. Ann., Erg. B., v, p. 373, 1871.

It is evident from the above that the first three minerals form a crystallographic series and that all of the forms occurring on them could practically be referred to one system of axes, but by so doing the parameter relations on the vertical axis would become exceedingly complicated. Chondrodite and clinohumite, although their inclination β is 90°, are monoclinic both as regards the symmetry in the development of the faces and their optical properties, chondrodite showing an extinction of 26°–30° and clinohumite $7\frac{1}{2}°$–$12\frac{1}{2}°$ from the vertical axis, while humite in all of its properties is orthorhombic.

The chemical relations of the minerals have never been satisfactorily determined. This is owing partly to the fact that it has been difficult to obtain pure material in sufficient quantity for analysis, while the analytical difficulties in the accurate determinations of silica and fluorine have not always been overcome. Water in the form of hydroxyl, which is an unfailing constituent of the minerals, has either been overlooked or incorrectly determined. Scacchi* regarded the minerals as representing three types of crystallization of one and the same chemical substance, which he designated as humite type I, type II and type III. Rammelsberg† and vom Rath‡ have suggested for the whole group the formula $Mg_5Si_2O_9$, with part of the oxygen replaced by fluorine, although they recognized that the percentages of silica varied in the different types. Wingard§ also, from the results of his recent analyses, concludes that the three minerals have the same chemical composition, expressed by the formula $Mg_{19}F_4(OH)_2Si_8O_{36}$, while Hj. Sjögren,‖ largely from a recalculation of the older analyses and a consideration that water had been overlooked in them, derived a separate formula for each species, as follows:

Clinohumite ----------	$Mg_5[Mg(OH.F)]_2[SiO_4]_2$
Humite ----------	$Mg_3[Mg(OH.F)]_2[SiO_4]_2$
Chondrodite ----------	$Mg_4[Mg(OH.F)]_2[SiO_4]_2$

Sjögren assumes that hydroxyl is isomorphous with fluorine and calls attention to the fact, already suggested by Rammelsberg and vom Rath, that the three minerals show a variation in their silica percentages.

In the present investigation we have been able to examine the following materials: Chondrodite from Warwick and Brewster's, New York; Kafveltorp, Sweden and Mte. Somma, Italy. Humite and Clinohumite from Mte. Somma.

* Loc. cit.
† Mineralchemie, p. 434, 1875.
‡ Pogg. Ann., cxlvii, p. 254, 1872.
§ Zeitschr. Anal. Chem., xxiv, p. 344, 1885.
‖ Zeitschr. Kryst., vii, p. 354, 1883.

After having definitely determined the crystallographic character of the minerals they were pulverized and sifted to a uniform grain and separated from the gangue and other impurities by means of the barium-mercuric-iodide solution. Thanks to this accurate method of separation we have had an advantage over all previous investigators in being able to obtain an abundance of material for the chemical analyses. Each product that was obtained was nearly uniform in specific gravity and almost absolutely pure, as shown by examination with the polarizing microscope.

Method of analysis.—Silica, fluorine and bases were determined in one portion, usually of from one to two grams, which was fused with a mixture of sodium and potassium carbonates and treated according to the Berzelius method of analyzing silicates containing fluorine. On soaking out the fusion with water in a platinum dish it was found that, owing to the basic character of the mineral, only a small quantity of silica had gone into solution, and this was separated directly by means of zinc oxide dissolved in ammonia, thus avoiding the customary precipitation with ammonium carbonate. The solution filtered from the zinc oxide and silica, and containing the alkali carbonate and fluoride, was nearly neutralized with hydrochloric acid, heated to boiling, and calcium fluoride and carbonate precipitated by addition of calcium chloride. After collecting the precipitate it was ignited to low redness in a weighed platinum crucible and the calcium carbonate or oxide removed by means of acetic acid. At this point we have usually proceeded as follows: To the ignited precipitate in the crucible water and 1 or 2^{cc} of acetic acid were added, the whole was then digested for some time on the water bath with the crucible covered, finally the cover was removed and the excess of acid evaporated. The dry salts were then extracted with hot water and the solution filtered through a small filter. After washing, the paper was burned in the same crucible, the residue treated again with water and a small quantity of acetic acid, the operation being repeated until all of the calcium carbonate and oxide had been extracted. Our experience has shown that a large excess of acetic acid used at once gives too low results. This method is not very tedious and is satisfactory, as shown by the following test experiments where determinations were made with known weights of pure fluorite mixed with chrysolite in the proper proportion to give amounts of fluorine and magnesium silicate about equal to those in chondrodite.

Chrysolite.	CaFe taken.	Equivalent of fluorine.	Fluorine found.	Loss.
1·3782	·2942	·1438	·1416	·0022
1·3794	·3012	·1473	·1456	·0017

These results, although low, are within 0·15 and 0·10 per cent of the theory when expressed in terms of the mixture of chrysolite and fluorite. The iron was separated from magnesia by ammonium, the precipitation being repeated at least twice to ensure a complete separation. Water was sometimes weighed directly in a U tube containing sulphuric acid, the mineral being fused with anhydrous sodium carbonate in a Gooch* tubulated crucible, special pains being taken to surround the crucible in which the fusion was made by a larger one containing sodium carbonate. Thus the gas flame never came into direct contact with the inner crucible and the passage of gases through the red hot platinum, which would have rendered the results too high was avoided. This method has been carefully tested by us and gives accurate results. In some analyses, where the percentage of ferrous oxide was small, water was determined as loss on ignition, as follows: About 0·4 gram of lime was ignited to a constant weight in a platinum crucible, into which subsequently the mineral was weighed. The lime was then carefully slaked and mixed with sufficient water to make a thin paste; after drying down on the water bath the crucible was ignited, gently at first, finally over the blast lamp, to a constant weight. The lime keeps fluorine from escaping and the error which would result from the complete oxidation of the iron would amount only to a few hundredths of one per cent. Duplicate determinations made by both methods agreed very well with one another. The water determined in the analyses must have come from hydroxyl as it cannot be completely expelled from chondrodite except by intense ignition. Thus a sample from Warwick, N. Y., which by direct determination yielded 1·43 and 1·48 per cent, gave only 0·48 per cent when ignited in a glass tube over the blast lamp, lime being used to retain the fluorine. The method that has been usually adopted of igniting with lead oxide was also tested and found to be wholly unsuitable, two determinations yielding only 0·77 and 0·56 per cent.

Chondrodite, (Humite Type II of Scacchi.)

Chondrodite from Warwick, Orange Co., N. Y. — The material that was selected for analysis was obtained from a specimen in the Brush collection, Catalogue No. 2054. The chondrodite occurs as rounded grains, of a rich reddish-brown color imbedded in a white crystalline limestone and associated with spinel and graphite. The material was very fresh and showed occasional crystal faces, but not sufficient for the identification of the mineral. It was selected at the beginning of

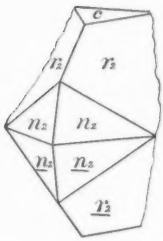
* Am. Chem. Jour., ii, p. 247, 1880.

our investigation as it afforded abundant material for testing the methods of the mechanical separation and the chemical analysis. The powder separated by the heavy solution varied in specific gravity between the limits 3·165 and 3·235. It showed only a trace of impurities when examined with the microscope, probably of partly altered spinel, which accounts for the small amount of Al_2O_3 shown by the analysis. That the mineral is really chondrodite is proved by the chemical analysis, as will be shown later, while from the same locality there is in the Brush collection a small specimen, Catalogue No. 2057, corresponding exactly in color and showing crystals that could be measured and identified as chondrodite. These are associated with an ash-gray amphibole and have evidently weathered out from limestone.

The crystals are attached so that only the following forms could be identified:

c, 001, O n_2, 111, -1 r_2, 125, $-\frac{2}{5}$-2

1.



A hemidome, probably $\bar{1}02$ or $\bar{3}05$ was also present but could not be identified with certainty. The crystals are twinned about the base and have the habit shown in figure 1. Only approximate measurements could be made.

	Measured.	Calculated for chondrodite.
$c \wedge n_2$, $001 \wedge 111$	= 76° 30′	76° 50′
$c \wedge r_2$, $001 \wedge 125$	= 54	54 10
$r_2 \wedge r_2$, $125 \wedge 1\bar{2}5$	= 94	94 51½

The analysis will be given later.

Chondrodite from the Tilly-Foster mine Brewster, Putnam Co., N. Y.—The material for analysis was selected wholly from isolated crystals, which were obtained by the authors at the locality. Each crystal was measured and found to possess characteristic chondrodite forms. The habits of different crystals varied considerably but conformed in general to types figured by E. S. Dana. The forms identified by us and some of the measured angles are the following:

b, 010, i-$\bar{\imath}$ $-n_2$, $\bar{1}11$, 1 r_1, $\bar{1}27$, $\frac{2}{7}$-$\bar{2}$

c, 001, O r_2, 125, $-\frac{2}{5}$-$\bar{2}$ r_3, $\bar{1}23$, $\frac{2}{3}$-$\bar{2}$

i_1, 012, $\frac{1}{2}$-$\bar{\imath}$ r_4, 121, -2-$\bar{2}$ m_2, $\bar{3}21$, 3-$\frac{3}{2}$

		Measured.	Calculated.
$r_2 \wedge r_2$,	$125 \wedge 1\bar{2}5$	= 94° 51′	94° 51½′
$r_1 \wedge r_1$,	$\bar{1}27 \wedge \bar{1}\bar{2}7$	= 79 15	79 24
$r_3 \wedge r_3$,	$\bar{1}23 \wedge \cdot\bar{2}3$	= 112 43½	112 55
$r_1 \wedge r_3$,	$\bar{1}27 \wedge \bar{1}23$	= 21 54	21 53

		Measured.	Calculated.
$r_3 \wedge r_4$,	$12\bar{3} \wedge 121$	= 31° 39½′	31° 39′
$b \wedge r_4$,	$010 \wedge 121$	= 26 3	25 58
$r_3 \wedge n_2$,	$\bar{1}23 \wedge \perp 11$	= 19 42	19 31½
$m_2 \wedge n_2$,	$\bar{3}21 \wedge \bar{1}11$	= 13 46	13 42

The crystals were exceptionally fresh and pure, and showed no trace of serpentinization. Some pure transparent pieces were selected for analysis by hand picking, while crystals having gangue attached to them were pulverized and separated by the heavy solution, the powder that was used in the analysis varying in specific gravity from 3·204 to 3·231.

Chondrodite from Kafveltorp, Sweden.—The material for our investigation was obtained from a specimen in the Brush collection, Catalogue No. 2040. The crystals have a yellowish brown color, are imbedded in sulphides, and their habit as well as this unusual association agree exactly with the description given by Hj. Sjögren;* the accompanying minerals being chiefly galena and sphalerite with a little chalcopyrite and amphibole. Only fragmentary crystals could be separated from the gangue, and the forms developed on one of these is shown in fig. 2, which is a projection upon $0\bar{1}0$. Some of the measured and calculated angles are:

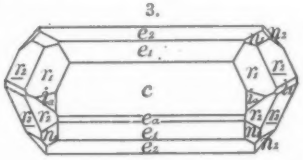
2.

		Measured.	Calculated.			Measured.	Calculated.
$c \wedge r_2$,	$001 \wedge 125 =$	53° 51′	54° 10′	$b \wedge r_4$,	$010 \wedge 121 =$	26° 24′	25° 58′
$r_2 \wedge r_4$,	$125 \wedge 121 =$	27 38	27 37	$c \wedge n_2$,	$001 \wedge 111 =$	77 3	76 50
$r_4 \wedge r_3$,	$121 \wedge 12\bar{3} =$	31 45	31 39	$n_2 \wedge -n_2$,	$111 \wedge 11\bar{1} =$	26 18	26 40

The material for analysis was separated by the heavy solution and varied in specific gravity from 3·252 to 3·265.

Chondrodite from Mte. Somma, Italy.—Our material was selected from a specimen in the Brush collection, Cat. No. 2063, which had been presented to Prof. Brush by Prof. A. Scacchi. The associated minerals constituting the gangue are calcite and biotite (meroxene). The crystals are honey-yellow in color, transparent and present the forms shown in the basal projection, fig. 3, the measured angles being:

3.



		Measured.	Calculated.			Measured.	Calculated.
$c \wedge e_2$,	$001 \wedge 101 =$	70° 52′	70° 56½′	$c \wedge r_2$,	$001 \wedge \bar{1}25 =$	54° 13′	54° 10′
$c \wedge -e_2$,	$001 \wedge \bar{1}01 =$	70 48	70 56½	$c \wedge r_1$,	$001 \wedge \bar{1}27 =$	44 35	44 41
$c \wedge e_1$,	$001 \wedge 103 =$	44 1	43 59	$c \wedge r_3$,	$001 \wedge \bar{1}23 =$	66 24	66 34
$c \wedge -e_1$,	$001 \wedge \bar{1}03 =$	43 52	43 59	$c \wedge n$,	$001 \wedge 113 =$	54 45	54 56
$c \wedge e_a$,	$001 \wedge 105 =$	29 55	30 4	$c \wedge -n$,	$001 \wedge \bar{1}13 =$	54 54	54 56
$c \wedge i_1$,	$001 \wedge 012 =$	57 24	57 33	$c \wedge n_a$,	$001 \wedge 111 =$	76 38	76 50
$c \wedge i_a$,	$001 \wedge 014 =$	38 4	38 10½	$c \wedge -n_a$,	$001 \wedge \bar{1}11 =$	76 46	76 50

* Zeitschr. Kryst., vii, p. 113, 1883.

The crystal that was measured was probably twinned about the base, the twinning plane being situated somewhat above the center which accounts for r_2 being situated under r_1 behind, and r_3 under r_2 in front, which is contrary to the usual arrangement of these planes in chondrodite. All of the crystals on the specimen had exactly the same color and general appearance and, although only one was measured it was assumed that they all belonged to the chondrodite type. This is rendered all the more probable by the observations of Scacchi* who states that, on a given block from Mte. Somma, usually only one type of humite occurs. The powder that was separated by the heavy solution varied in specific gravity between 3·194 and 3·215.

The analyses are as follows:

Warwick, N. Y.

Specific gravity = 3·168–3·235.

	I.	II.	III.	IV.	Average.	Ratio.	
SiO_2	33·85	33·67	33·82	33·86	33·80	0·563	0·563
MgO	55·74	55·87	55·78	55·68	55·70	1·396	1·433
FeO	2·59	2·64	2·69		2·64	·037	
Al_2O_3	1·79	1·87			1·83		
F	7·32	7·26	7·32		7·30	·384	0·546
H_2O	1·43	1·48			1·46÷9=	·162	
					102·73		
Oxygen equivalent to F =					3·07		
					99·66		

Brewster, N. Y.

Specific gravity = 3·204–3·231.

	I.	II.	III.	Average.	Ratio.	
SiO_2	33·66	33·48	33·87	33·67	·561	0·561
MgO	54·68	54·92	54·78	54·79	1·370	1·452
FeO	5·89	5·96	5·99	5·94	·082	
F	5·25	5·38	5·31	5·30	·279	0·593
H_2O	2·60	2·44	2·61	2·55÷9 =	·294	
				102·25		
Oxygen equivalent to F =				2·23		
				100·02		

* Pogg. Ann., Erg. B., iii, p. 181, 1851.

Kafveltorp, Sweden.

Specific gravity = 3·252–3·265.

	I.	II.	III.	IV.	Average.	Ratio.	
SiO_2	33·36	33·28	33·18	33·52	33·33	·556	0·556
MgO	54·23	54·37			54·30	1·358	1·450
FeO	6·66	6·58			6·62	·092	
F	6·74	6·58	6·63	6·43	6·60	·347	0·533
H_2O	1·63	1·72			1·67÷9 =	·186	
					102·52		
Oxygen equivalent to F =					2·76		
					99·76		

Mte. Somma, Italy.

Specific gravity = 3·194–3·215.

	I.	II.	Average.	Ratio.	
SiO_2	33·96	33·78	33·87	·564	0·564
MgO	56·37	56·55	56·46	1·411	1·461
FeO	3·72	3·60	3·66	·050	
F	5·09	5·21	5·15	·271	0·584
H_2O	2·92	2·72	2·82÷9 =	·313	
			101·96		
Oxygen equivalent to F =			2·16		
			99·80		

In discussing the above analyses it has been assumed that FeO is isomorphous with MgO and hydroxyl with fluorine. The ratios have been collected together in the following table:

	SiO_2	: (MgO + FeO)	: (F + OH)	
Warwick,	0·563	: 1·433	: 0·546 = 1·96	: 5 : 1·90
Brewster,	0·561	: 1·452	: 0·593 = 1·93	: 5 : 2·04
Kafveltorp,	0·556	: 1·450	: 0·533 = 1·92	: 5 : 1·84
Mte. Somma,	0·564	: 1·461	: 0·584 = 1·93	: 5 : 1·99

These all approximate to $SiO_2 : RO : (F+OH) = 2 : 5 : 2$ which would give for the formula of chondrodite, $Mg_5(F.OH)_2Si_2O_8$ or an isomorphous mixture of the molecules $Mg_3(MgF)_2(SiO_4)_2$ and $Mg_3(MgOH)_2(SiO_4)_2$. The ratio of fluorine to hydroxyl, or of these two molecules varies considerably. In the Brewster and Mte. Somma minerals it is nearly 1 : 1, in Kafveltorp 2 : 1 and in Warwick $2\frac{1}{3}$: 1. The specific gravities are very close, varying only between 3·165 and 3·265 and, as would be expected, increase with the percentage of iron.

For a better comparison of the analyses with the theory they are given below after recalculating FeO as MgO and bringing the total to one hundred per cent.

	Brewster.	Mte. Somma.	Theory where F : OH = 1 : 1.
SiO_2	34·56	34·52	35·29
MgO	59·69	59·56	58·82
F	5·44	5·25	5·59
H_2O	2·62	2·88	2·65
	102·31	102·21	102·35
O. eq. to F =	2·31	2·21	2·35

	Warwick.	Kafveltorp.	Theory where F : OH = 2 : 1.
SiO_2	34·91	34·42	35·22
MgO	59·23	59·90	58·71
F	7·54	6·81	7·44
H_2O	1·51	1·73	1·76
	103·19	102·86	103·13
O. eq. to F =	3·19	2·86	3·13

These analyses are all slightly high in magnesia and correspondingly low in silica and (F+OH), but on the whole they agree very well with the theory.

Previous analyses of chondrodite.—In discussing the analyses of other investigators it must be borne in mind that water has usually been disregarded or determined incorrectly. We have tabulated below the available analyses that have been made on material of known crystallographic character.

From Mte. Somma.

I. Rammelsberg.* Brownish yellow crystals. Mean of two analyses.
II. G. vom Rath. Light yellow crystals. Mean of two analyses.
III. Wingard. Light wine yellow crystals. Mean of two analyses.

From Kafveltorp, Sweden.

IV. Wingard. Wine yellow crystals. Mean of three analyses.
V. G. vom Rath. Mean of two analyses.
VI. Hj. Sjögren.† Brown crystals.
VII. Hj. Sjögren. Yellow crystals.

From Brewster, N. Y.

VIII. Hawes.‡ Garnet red crystals. Measured and identified by E. S. Dana. Mean of two analyses.

* Pogg. Ann., lxxxvi, p. 413, 1852.
† Zeitschr. Kryst., vii, p. 356, 1883.
‡ Trans. Conn. Acad., iii, p. 86, 1874.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Sp. gr.	3·190	3·125	----	----	----	----	----	3·22
SiO_2	33·26	33·92	33·63	33·60	33·66	33·13	34·01	34·08
MgO	57·92	59·33	58·13	53·05	53·26	54·71	54·97	53·44
FeO	2·30	1·71	3·88	8·67	6·82	4·95	4·62	7·22
F	5·04	2·59	5·20	5·58	4·24	4·99	4·56	4·01
H_2O	----	----	1·37	1·31	---	·55	·61	----
Al_2O_3	1·06	·97	----	----	·67	·68	·71	·44
CaO	·74	----	----	Fe_2O_3 ·12	----	MnO ·75	MnO ·18	----
	100·32	98·52	102·21	102·33	98·65	99·76	100·29	99·19
O = F	2·12	1·09	2·19	2·35	1·78	2·10	1·92	1·69
	98·20	97·43	100·02	99·98	96·87	97·66	98·37	97·50
Cal. H_2O	*2·94*	*4·19*	*1·58*	*1·24*	*3·12*	*2·29*	*2·45*	*3·27*
	101·14	101·62	101·60	101·22	99·99	99·95	100·82	100·77

With two exceptions, analyses III and IV, it will be observed that after deducting the oxygen equivalent to fluorine the analyses add up to only about 96 to 98 per cent, and it is believed that this loss must be due to water which was not determined. Taking the protoxides, MgO and FeO, as a basis of calculation, we have determined the amounts of water which should be added to the analyses in order to yield the ratio $RO : (F+OH) = 5 : 2$ established by us. These quantities (*Cal. H_2O*) when added give very satisfactory results. In all of the analyses except those of Wingard, III and IV, the summation is nearer 100 per cent than before and this is especially shown in the last four. This method of treating the water is probably fairer than to derive it from the deficiency in the analyses, as by the latter treatment, all of the errors of analysis would be thrown upon this constituent, which, owing to its low molecular weight, needs to be very accurately determined to yield a sharp and correct ratio. The percentages of SiO_2 vary from 33·13 to 34·08 while in our analyses they run from 33·33 to 33·87. In the following table, where the ratios of $SiO_2 : RO$ are given, it may be observed that they approximate closely to 2 : 5 as required by our formula.

	$SiO_2 : RO$		$SiO_2 : RO$
I.	·554 : 1·489 = 1·88 : 5	V.	·561 : 1·426 = 1·96 : 5
II.	·565 : 1·507 = 1·88 : 5	VI.	·552 : 1·447 = 1·91 : 5
III.	·561 : 1·507 = 1·86 : 5	VII.	·567 : 1·448 = 1·96 : 5
IV.	·560 : 1·446 = 1·94 : 5	VIII.	·568 : 1·436 = 1·98 : 5

It is very gratifying to be able to show that the formula established by us is thus substantiated by the analyses of previous investigators.

Humite, (Type I of Scacchi.)

In the course of the investigation we have been able to examine only the humite from Mte. Somma, of which two separate samples were analyzed. The material for the first of these was obtained from a specimen purchased from Dr. A. E. Foote of Philadelphia. The humite crystals, which measure from 2–3^{mm} in diameter, are nearly colorless and transparent and are associated with spinel and calcite. Their habit corresponds in general to the figure of vom Rath* copied into the sixth edition of Dana's Mineralogy, page 535. Some of the measured angles are as follows:

		Measured.	Calculated.			Measured.	Calculated.
$c \wedge e_2$,	$001 \wedge 104$	$= 45° 29'$	$45° 32\frac{1}{2}'$	$c \wedge r_2$,	$001 \wedge 128$	$= 50° 31\frac{1}{2}'$	$50° 30'$
$c \wedge e_4$,	$001 \wedge 102$	$= 63\ 51$	$63\ 52$	$c \wedge r_3$,	$001 \wedge 126$	$= 58\ 16$	$58\ 16$
$c \wedge e_6$,	$001 \wedge 101$	$= 76\ 17$	$76\ 13$	$c \wedge i_2$,	$001 \wedge 013$	$= 55\ 45$	$55\ 44$
$c \wedge r_1$,	$001 \wedge 1\cdot2\cdot10$	$= 44\ 9\frac{1}{2}$	$44\ 8\frac{1}{2}$	$c \wedge i_3$,	$001 \wedge 011$	$= 76\ 59$	$77\ 12$

The material that was separated for analysis varied in specific gravity from 3·194 to 3·201

The material for the second analysis was selected from a specimen in the Yale College cabinet, Catalogue No. 4102. The crystals are associated with calcite and biotite. They are chestnut brown in color, in habit like the ones described above and were identified by the following measurements.

	Measured.	Calculated.
$c \wedge i_2$, $001 \wedge 013$	$= 55° 44'$	$55° 44'$
$c \wedge i_2$, $001 \wedge 0\bar{1}3$	$= 55\ 49$	" "

The specific gravity of the material for analysis varied from 3·183 to 3·225.

First Analysis.

	I.	II.	III.	IV.	Average.	Ratio.	
SiO_2	36·59	36·63	36·63	36·68	36·63	·6105	
MgO	56·34	56·43	56·59	56·45	56·45	1·411	1·444
FeO	2·33	2·43	2·46	2·30	2·35	·033	
F	3·12	3·06	2·96	....	3·08	·162	·423
H_2O	2·42	2·48			2·45 ÷ 9 =	·261	
					100·96		
		Oxygen equivalent to F			1·26		
					99·70		

* Pogg. Ann. Erg. B., v, Table VII, fig. 1.

Second Analysis.

	I.	II.	Average.	Ratio.	
SiO_2	36·84	36·63	36·74	·612	
MgO	56·21	56·42	56·31	1·408	1·437
FeO	2·22	2·21	2·22	·029	
F	3·89	4·02	3·96	·208	·444
H_2O	2·18	2·08	2·13÷9	·236	
			101·36		
Oxygen equivalent to F =			1·66		
			99·70		

These analyses differ from those of chondrodite in being about 3 per cent higher in silica and also the ratios are different as shown by the following:

	SiO_2	: (MgO + FeO)	: (F + OH)
1st Analysis,	0·6105 :	1·444	: 0·423 = 2·97 : 7 : 2·05
2d Analysis,	0·612 :	1·437	: 0·444 = 2·99 : 7 : 2·16

These ratios approximate closely to 3 : 7 : 2, indicating that the formula of humite is $Mg_5[Mg(F.OH)]_2[SiO_4]_3$. The ratio of F : OH in the first analysis is nearly 2 : 3 and in the second about 1 : 1. We give beyond the theoretical composition for both ratios, together with the analyses in which the FeO has been calculated as MgO and the total brought to 100 per cent.

	First analysis.	Theory where F : OH = 2 : 3.	Second analysis.	Theory where F : OH = 1 : 1.
SiO_2	37·15	37·53	37·24	37·50
MgO	58·56	58·38	58·27	58·34
F	3·12	3·17	4·02	3·96
H_2O	2·48	2·25	2·16	1·87
	101·31	101·33	101·69	101·67
O eq. to F	1·31	1·33	1·69	1·67

These analyses show a very satisfactory agreement with the theory and we may regard the formula of humite as well established.

Previous analyses of humite.—The following analyses are available for comparison.

From Mte. Somma.

I. Rammelsberg. Grayish yellow crystals.
II. G. vom Rath. Light brown crystals. Mean of two analyses.
III. Wingard. Light yellow crystals. Mean of two analyses.
IV. Wingard. Dark yellow crystals.

From Ladu Mine, Sweden.

V. Wingard. Material described as not quite pure and showing traces of serpentinization, which accounts for the high percentage of H_2O.

VI. Hj. Sjögren.

	I.	II.	III.	IV.	V.	VI.
Sp. gr.	3·216	3·208	----	----	----	----
SiO_2	34·80	35·49	35·43	35·55	35·26	35·13
MgO	60·08	54·28	56·29	52·86	55·48	55·16
FeO	2·40	5·12	3·70	7·31	3·51	3·26
	----	CaO ·20	----	----	----	MnO ·41
	----	Al_2O_3 ·76	----	----	----	----
F	3·47	2·43	5·63	5·60	4·72	2·45
H_2O	----	----	1·48	1·37	3·07	2·16
	100·75	98·28	102·53	102·69	102·04	98·57
O eq. to F	1·46	1·02	2·37	2·36	1·98	1·03
	99·29	97·26	100·16	100·33	100·06	97·54
Cal. H_2O	*2·29*	*2·52*	----	----	----	*·35*
	101·58	99·78				97·89

It will be observed that these analyses show percentages of SiO_2 varying from 34·80–35·55, agreeing with those made by us in being higher than the corresponding percentages in chondrodite. The *calculated water* represents the amount required to yield the ratio of $RO:(F+OH) = 7:2$. When added to analysis II it makes the summation very satisfactory but causes I to overrun. In the analyses of Wingard there are already sufficient quantities of F and H_2O to give the required ratio. Sjögren's analysis is evidently too low. The ratios are as follows:

	SiO_2 :	RO :	(F+OH)
I.	0·580 :	1·535 :	---- = 2·65 : 7 : ----
II.	0·592 :	1·428 :	---- = 2·90 : 7 : ----
III.	0·591 :	1·458 :	0·460 = 2·84 : 7 : 2·21
IV.	0·593 :	1·422 :	0·447 = 2·92 : 7 : 2·20
V.	0·588 :	1·436 :	0·589 = 2·87 : 7 : (2·8 ?)
VI.	0·586 :	1·430 :	0·369 = 2·87 : 7 : 1·8

These ratios of $SiO_2:RO$ approximate closely to 3 : 7 as required by our formula and in analyses III, IV and VI the (F+OH) is not far from the correct ratio which should be $RO:(F+OH) = 7:2$. Thus our formula for humite is also substantiated by the analyses of other investigators.

Clinohumite, (*Humite Type III of Scacchi.*)

Of this rare mineral we have been able to examine two specimens from Mte. Somma. For the first analysis the material was derived from a specimen in the Brush collection, cata-

logue No. 2064, which had been presented by W. Sartorius von Waltershausen. The crystals are light wine yellow, transparent and in habit like the simple crystals figured by vom Rath.* The associated minerals are, forsterite, biotite, spinel, calcite and a little vesuvianite. The measurements that served for the identification of the mineral are as follows:

		Measured.	Calculated.
$c \wedge e_4$,	$001 \wedge 101 =$	79° 12′	79° 11½′
$c \wedge e_3$,	$001 \wedge 103 =$	60 13	60 12
$c \wedge e_2$,	$001 \wedge 105 =$	46 24	46 20
$c \wedge e_1$,	$001 \wedge 107 =$	36 49	36 48½
$c \wedge -e_1$,	$001 \wedge \bar{1}07 =$	36 49	36 48½
$c \wedge i_2$,	$001 \wedge 014 =$	54 43	54 45
$c \wedge i_1$,	$001 \wedge 016 =$	43 19	43 19½

		Measured.	Calculated.
$c \wedge r_5$,	$001 \wedge \bar{1}27 =$	60° 42′	60° 42′
$c \wedge r_3$,	$001 \wedge \bar{1}\cdot2\cdot11 =$	48 35	48 35
$c \wedge r_1$,	$001 \wedge \bar{1}\cdot2\cdot15 =$	39 46	39 44½
$c \wedge r_2$,	$001 \wedge 1\cdot2\cdot13 =$	43 49	43 49
$c \wedge r_4$,	$001 \wedge 129 =$	54 10	54 11
$c \wedge n_2$,	$001 \wedge 115 =$	57 2	57 2½

The specific gravity, when taken with the heavy solution, varied between 3·184 and 3·222 and this being almost identical with that of forsterite the yellow clinohumite crystals had to be separated from the colorless forsterite by hand picking. The specimen only afforded 0·3879 grams of the mineral and the analysis was made on this small portion by fusing the whole with dry sodium carbonate in the Gooch crucible to obtain the water, soaking out the fusion and carrying on the analysis in the usual way. In the course of the analysis a most unusual accident occurred. The platinum crucible in which the fusion was made broke, and it was not discovered till, on soaking out the fusion, it was found to leak. The break was of such a nature that the water determination was not lost and the mechanical loss, caused by the leaking, was slight and, in all probability, evenly distributed on the remaining constituents. It is assumed that the deficiency of the analysis, amounting to about 2 per cent, was caused by this accident, as otherwise the analysis was carried on with more than usual care. The analysis is given beyond under *a* as it stands in the note book and under *b* after distributing the deficiency of 2·28 per cent among all of the constituents except water.

The material for the second analysis was derived from a specimen in the Yale College cabinet, catalogue No. 4143. The crystals are chestnut brown in color and are associated with forsterite, biotite, vesuvianite and a little calcite. Their identity as clinohumite is shown by the following measurements.

		Measured.	Calculated.
$c \wedge -e_1$,	$001 \wedge \bar{1}07 =$	36° 45′	36° 48½′
$c \wedge e_{\frac{1}{3}}$,	$001 \wedge 109 =$	30 00	30 12
$c \wedge e_2$,	$001 \wedge 105 =$	46 19	46 20
$c \wedge e_3$,	$001 \wedge 103 =$	60 12	60 12
$c \wedge e_4$,	$001 \wedge 101 =$	79 9	79 11½
$c \wedge i_1$,	$001 \wedge 016 =$	43 19	43 19½

		Measured.	Calculated.
$c \wedge i_2$,	$001 \wedge 014 =$	54° 40′	54° 45′
$c \wedge r_3$,	$001 \wedge \bar{1}\cdot2\cdot11 =$	48 28	48 35
$c \wedge r_5$,	$001 \wedge \bar{1}27 =$	60 41	60 42
$c \wedge -n_2$,	$001 \wedge \bar{1}15 =$	57 2	57 2½
$c \wedge -n_4$,	$001 \wedge \bar{1}11 =$	82 49	82 37

* Pogg. Ann., Erg. B. v, Tables VI, figs. 1 and 7 and VII, fig. 10. Sixth edition of Dana's Mineralogy, page 538.

The material for the analysis had to be selected by hand picking and, when introduced into the heavy solution, showed a specific gravity between the limits 3·219 and 3·258. The analyses are as follows:

First Analysis.

	a.	*b.*			Ratio.
SiO_2	37·15	38·03	·634		4·02
MgO	52·74	54·00	1·350	1·417	9·00
FeO	4·72	4·83	·067		
F	2·01	2·06	·108	·323	2·05
H_2O	1·94	1·94÷9 =	·215		
	98·56	100·86			
O eq. to F =	·84	·86			
	97·72	100·00			

Second Analysis.

				Ratio.
SiO_2	37·78	·629		4·03
MgO	53·05	1·326	1·404	9·00
FeO	5·64	·078		
F	3·58	·188	·336	2·15
H_2O	1·33÷9 =	·148		
	101·38			
O eq. to F =	1·50			
	99·88			

In both of these analyses the ratios of $SiO_2 : RO : (F+OH)$ approximate closely to 4 : 9 : 2 corresponding to the formula $Mg_7[Mg(FOH)]_2(SiO_4)_4$. In the first analysis, the ratio of F : OH = 1 : 2 and in the second it is about 1 : 1. Below we have given the analyses after calculating FeO as MgO and bringing them to 100 per cent and, for comparison, the theoretical composition according to the above formula with F : OH = 1 : 2 and 1 : 1 respectively.

	First analysis.	Theory where F : OH = 1 : 2.	Second analysis.	Theory where F : OH = 1 : 1.
SiO_2	38·87	38·75	38·81	38·77
MgO	57·94	58·12	57·64	58·16
F	2·10	2·05	3·68	3·07
H_2O	1·98	1·94	1·37	1·29
	100·89	100·86	101·50	101·29
O eq. to F	·89	·86	1·50	1·29

The agreement of the above analyses with the theory is very satisfactory.

Previous analyses of Clinohumite.—The following analyses are available for comparison, all made on mineral from Mte. Somma.

I. Rammelsberg. Yellowish white crystals. Mean of three analyses.

II. Rammelsberg. One of the above analyses showing the highest SiO_2 and MgO.

III. G. vom Rath. Orange yellow crystals. Mean of two analyses.

IV. Wingard. Grayish to yellowish brown crystals. Mean of two analyses.

	I.	II.	III.	IV.
SiO_2	36·67	37·23	36·75	33·30
MgO	56·83	57·78	54·88	51·53
FeO	1·67	1·57	5·48	9·71
	----	----	Al_2O_3 ·24	Fe_2O_3 ·89
F	2·62	2·33	2·30	5·67
H_2O	----	----	----	1·41
	97·79	98·91	99·65	102·51
O eq. to F	1·10	·98	·97	2·38
	96·69	97·93	98·68	100·13
Cal. H_2O	*1·64*	*1·83*	*1·81*	*1·03*
	98·33	99·76	100·49	101·16

In the first three analyses the *calculated water* represents the quantity necessary to yield the ratio $RO : (F+OH) = 9 : 2$, and as in previous instances it makes the analyses add up much nearer 100 per cent than before. The ratios are as follows:

	SiO_2 : RO
I.	·611 : 1·444 = 3·80 : 9
II.	·621 : 1·466 = 3·81 : 9
III.	·613 : 1·448 = 3·81 : 9

These approximate to 4 : 9 and thus substantiate in a satisfactory manner our formula for clinohumite.

The results of Wingard, analysis IV, differ from those of other investigators. No proof is given that the material which he analyzed is clinohumite except that it was obtained from Prof. Scacchi, and there has undoubtedly been some mistake for his analysis yields a ratio of $SiO_2 : RO = 1·95 : 5$, which is very close to 2 : 5 as required by our formula for chondrodite. The fluorine and water are low, as in his other chondrodite analyses and the *calculated water* that we have added is that required to complete the ratio $SiO_2 : RO : (F+OH) = 2 : 5 : 2$.

Conclusions.—In the preceding pages we have shown that the minerals of the humite group are *not* identical with each other in chemical composition and that they can be expressed by the following formulæ, constructed on two, three and four molecules of ortho silicic acid, in which two hydrogen atoms are replaced by the univalent radical [Mg(F . OH)] and the remaining ones by magnesium :

Chondrodite	$Mg_3[Mg(F.OH)]_2[SiO_4]_2$
Humite	$Mg_5[Mg(F.OH)]_2[SiO_4]_3$
Clinohumite	$Mg_7[Mg(F.OH)]_2[SiO_4]_4$

These form a chemical series, varying progressively from chondrodite to clinohumite by an increase of one molecule of Mg_2SiO_4. This variation in chemical composition is intimately connected with the crystallization. Thus on page 188 it was mentioned that the three minerals form a crystallographic series in which the vertical axes increase from chondrodite to clinohumite. It was also shown that by dividing the vertical axes by 5, 7 and 9 respectively the quotients become practically identical and it is a very interesting and remarkable fact that these divisors 5, 7 and 9 correspond to the number of magnesium atoms in the formulæ deduced by us. Groth* has shown that in certain organic compounds the substitution of one hydrogen atom by another atom or radical causes a change in one of the crystallographic axes, the other two and the symmetry remaining essentially unchanged. Such a crystallographic series he calls a "Morphotropische Reihe." In the humite group we evidently have a kind of morphotropic series, but not exactly analogous to that cited by Groth as in the present case we have a change brought about by the *addition* of a molecule of Mg_2SiO_4, instead of the substitution of a radical. This addition of Mg_2SiO_4 causes the vertical axis to increase by about 1·2575, or $\frac{1}{9}$ of the vertical axis of clinohumite, while the other two axes and the inclination β remain the same. The symmetry, however, changes so that the first and last members of the series are monoclinic. In the whole range of chemical crystallography there is no series of compounds known to the authors that can be compared to the humite group. It is reasonable to expect that other members of this series will be found. Thus $Mg[Mg(F.OH)]_2SiO_4$ is a possible and a most likely compound to occur. This should crystallize either orthorhombic or monoclinic with $\beta = 90°$ and should have the axial ratio $a : b : c = 1·086 : 1 : 1·887$. The member next beyond clinohumite would be $Mg_9[Mg(F.OH)]_2[SiO_4]_5$ but, owing to its more complicated composition, it would seem less apt to occur. Chrysolite, Mg_2SiO_4, is closely

* Monatsber. Berlin Akad., 1870, p. 247.

related to the members of this group and, as shown by vom Rath,* a few of its forms are almost identical with those of humite. Their relation is shown on page 188 where the axial ratio $b:2a:c$ of chrysolite is similar to $a:b\frac{1}{3}c$ of clinohumite. As chrysolite contains no fluorine or hydroxyl it deviates considerably in its chemical type from the members of the humite group and its crystalline habit is also different, as the majority of its common forms do not correspond to any of the forms of humite. Of the three species constituting the humite group chondrodite has the simplest composition and is the most common, clinohumite has the most complicated composition and is the rarest, while humite occupies an intermediate position. At Mte. Somma chondrodite, which is the most basic, occurs usually with calcite, while clinohumite, which is the most acid, is usually associated with the silicate forsterite.

Of the formulæ proposed by other investigators that suggested by Rammelsberg and vom Rath, $Mg_5Si_2O_9$, is similar to the one deduced by us for chondrodite. They considered that part of the oxygen was replaced by fluorine, while we have shown that *one atom* of oxygen is replaced by the isomorphous fluorine and hydroxyl. The formula proposed by Wingard, $Mg_{13}[MgF]_4[Mg(OH)]_2[SiO_4]_8$ or $Mg_{19}(F.OH)_6(SiO_4)_8$, is not very different from ours for humite, it being equal to three times the latter, $Mg_{21}(F.OH)_6(SiO_4)_9$, less Mg_2SiO_4. Wingard derived his formula from the analysis of humite given below which, like the accompanying analyses of chondrodite, have been changed from their original shape only by recalculating FeO as MgO and bringing the total to 100 per cent. His humite analysis, naturally, agrees very well with his theory, but it also agrees quite well with the author's, while his chondrodite analyses agree very indifferently with his theory.

	Author's theory for humite F : OH = 2 : 1.	Wingard's theory. F : OH = 2 : 1.	Humite. Anal. IV, p. 200.	Chondrodite. Anal. III, p. 197.	Anal. IV, p. 197.
SiO_2	37·45	36·87	36·63	34·21	35·01
MgO	58·25	58·38	58·62	61·33	60·29
F	5·27	5·84	5·77	5·29	5·81
H_2O	1·25	1·37	1·41	1·40	1·36
	102·22	102·46	102·43	102·23	102·47
O eq. to F	2·22	2·46	2·43	2·23	2·47

Our formulæ for the different members of the series do not agree in any single instance with those proposed by Sjögren, and yet his formulæ for the two upper members, humite and clinohumite, are identical with ours for chondrodite and humite respectively, as shown by the following:

* Pogg. Ann. Ergänz., Band V, p. 412, 1871.

	Authors.	Sjögren.
Chondrodite	$Mg_3[Mg(F.OH)]_2[SiO_4]_2$	$Mg_4[Mg(F.OH)]_4[SiO_4]_3$
Humite	$Mg_6[Mg(F.OH)]_2[SiO_4]_3$	$Mg_5[Mg(F.OH)]_2[SiO_4]_2$
Clinohumite	$Mg_7[Mg(F.OH)]_2[SiO_4]_4$	$Mg_6[Mg(F.OH)]_2[SiO_4]_3$

Sjögren was correct in assuming that hydroxyl is present in the minerals and that it is isomorphous with fluorine, but he failed to obtain the correct formulæ because he made direct comparisons of the silica percentages calculated from his formulæ, with the actual figures yielded by the older analyses which are somewhat low, while he neglected to take into consideration the fact that magnesia is partly replaced by ferrous oxide, which from its higher molecular weight still further lowers the percentage of silica. Thus it happens that, without making any correction for ferrous iron, the actual determinations of silica in the older analyses of humite and clinohumite agree very well with the formulæ proposed by him. To account for chondrodite, the most basic member of the series, Sjögren adopted a formula containing the Mg(F . OH) group four times. If in this F : OH = 1 : 1 then the calculated silica, 33·33 per cent, agrees very well the average *found* in the older analyses, which is about 33·5, but this should be nearly 35·0 when FeO is calculated to its equivalent of MgO and the analyses are brought to 100. Also the calculated percentages of F(7·04) and H_2O(3·33), taken together, are far in excess of anything observed in chondrodite. In the authors' formula the ratio of RO : (F+OH)=5 : 2 while in Sjögren's it is 5 : 2·5.

That fluorine is isomorphous with hydroxyl, or plays the same part in a molecule, seems too well established to need special comment. The results of our analyses indicate clearly that in the minerals of this group this isomorphism exists and if we abandon the idea a satisfactory explanation of their composition cannot be given. The theory that fluorine can replace oxygen, which formerly was so frequently advanced, is similar to our present idea that fluorine and hydroxyl are isomorphous, and the latter would seem to be the more natural for both fluorine and hydroxyl are univalent, the one having an atomic weight of 19 and the other a molecular weight of 17.

The formulæ thus proposed as the result of this investigation are simple and rational, they agree in a very satisfactory manner with the results of our analyses as well as with those of others and they constitute an extremely interesting chemical series, which is related in a remarkable manner to the crystallization of these minerals.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, December, 1893.

Art. XIX.—*Deformation of the Lundy Beach and Birth of Lake Erie;* by J. W. Spencer.

Contents.—A sequel to the Birth of Lake Ontario and Birth of Lake Huron; Epeirogenic elevation and dismemberment of Warren water: Formation of Lundy Lake and its Beach; Lundy Lake did not receive the waters from the Huron basin: Desertion of the Lundy shore, with the formation of Lake Erie and Niagara River; Deformation of the Lundy shore and the flooding of the head of the Erie basin; Warping northeast of the Huron basin, and its drainage turned into the Erie valley; Estimated rate of terrestrial warping; The future outlet of Lake Erie.

The history of Lake Erie is a natural sequel to the Birth of Lake Ontario* and the Birth of Lake Huron,† which have already appeared in this Journal. Deserted strands about Lake Erie have also been made known,‡ but all of them extended beyond the Erie basin, and formerly embraced the greatest of the inland sheets—the Warren water—which probably covered 200,000 square miles, or more than the entire area of the modern lakes. The last of the deserted shores of that body of water was the Forest beach (see map). The subsequent rise of land or subsidence of the waters has been intermittent with episodes of rest long enough for the waves to carve out broad terraces or build up heavy beaches. Still, the instability of the waters is marked by the greater beaches being composed of a series of beachlets rather than one individual mass. The series is remarkably persistent, although there may be imperfect development of the component parts. Between the different sets of deserted shores, there are often only traces of the receding water-levels.

In the survey of the Forest beach, fragments of old coast lines were observed below that level, and these have recently been found to form part of a great Erie shore, in age synchronous with the Algonquin beach of the higher lakes. This Erie beach, first described here, may appropriately be called the Lundy shore, after the spit near Niagara Falls, which has long been used as a ridge road, and known as Lundy Lane, and where the interpretation of the strand was discovered. The Algonquin and Lundy Lakes were the successors of the Warren water after its dismemberment by the level falling below that of Forest beach.

* "Deformation of the Iroquois Beach and Birth of Lake Ontario." This Journal, vol. xl, p. 443, 1890.

† "Deformation of the Algonquin Beach and Birth of Lake Huron." The same, vol. xli, p. 12, 1891.

‡ "High-level Shores in the Region of the Great Lakes and their Deformation." The same, vol. xli, p. 201—all by J. W. Spencer.

Between Font-hill and Ebenezer (see map) there was an extension of the Erie waters into the Ontario basin through a strait, if such it can be called, as it was over thirty miles across. The country in the Niagara district is a plain from

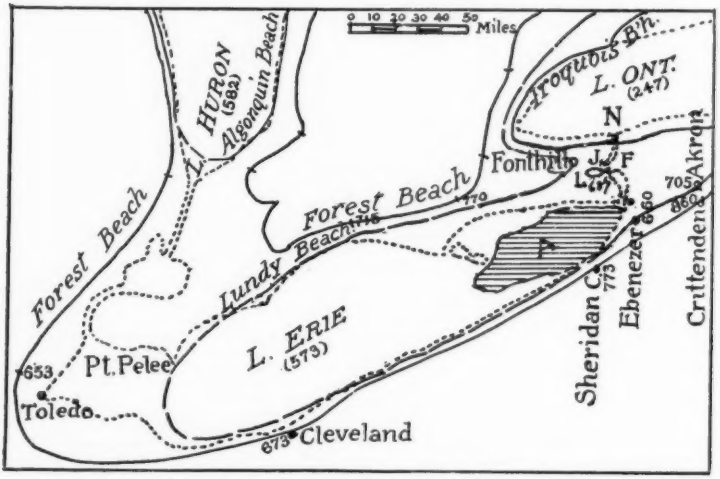


FIG. 1.—Map of Lundy shore, enclosing Lundy Lake. A, infant Lake Erie. N, mouth of Niagara River. F, Niagara Falls. L, Lundy beach near the Falls. J, Johnson's ridge. Elevations refer to sea-level.

10 to 15 feet above Erie Lake. It is rendered somewhat undulating by a few ridges of drift rarely rising 30 feet higher. A rocky ridge of 20 or 30 feet above the lake is parallel with the shores of Erie, a mile or two to the north of its outlet. But the most notable ridge culminated in Drummondville, near the falls, at 144 feet above the lake level. This is a small knob at the end of a long spit which is the historic Lundy Lane. The surface of this strand is 30 feet below the knob just noticed. This ridge formed a spit which was the first barrier that appeared between the Erie and Ontario basins, and here the waters last lingered before they subsided within the lower basin. The knob at Drummondville is not an undulation of the Lundy shore, although it is made up of beach-material, but belonged to a higher level. Whether a fragment of an older strand or not, still equivalent remains of deserted water-lines are found at Font-hill, Akron and elsewhere.

The crest of the Lundy beach is from 100 to 200 feet wide and forms a conspicuous sand and gravel ridge of more than double this width at the base, to which it slopes—20 or 30 feet below, and bounds an extensive plain on both sides, as it

constituted a spit between the Erie and Ontario basins, which were connected by a broad sheet of open water. After extending westward from the Niagara River for two or three miles, the Lundy beach is interrupted by a low plain, but again the strand skirts Font-hill (which rises about 300 feet above Lake Erie) and trends southwestward. On the southeastern side of the strait, the beach is equally characteristic, near Ebenezer. It has been traced to Akron or about five miles due north of Crittenden, where the Forest beach was surveyed several years ago by Mr. Gilbert.

At Ebenezer, the Lundy beach has an altitude of 660 feet (bar.) above tide (Lake Erie being 573 feet); at Lundy Lane the elevation is 687 feet (and the older knob 30 feet higher); at Font-hill it is 675 feet (bar.); at Akron, the upper ridgelet is 735 feet (bar.) or equivalent to the lower at 705 feet. Fragments of beaches and terraces have been made known about the head of Lake Ontario and also about the Erie basin, but they have not been previously correlated with the Lundy shore. The Lundy strand is between 140 and 155 feet below the plain of the Forest beach, and it is usually from two to five miles lakeward of it. Between the different strands of Warren water, there is a slight deformation of the deserted shores owing to the unequal terrestrial movement. A somewhat greater amount of warping is recorded between the Forest and the Lundy beeches but the greatest amount of deformation was after the dismemberment of Lundy Lake. West of Cleveland, very little deformation of the old waterlines has occurred. From the relation with the Forest beach, the extension of Lundy Lake towards the west can be approximately delimited. The lake reached to Point Pelée and the islands opposite. The eastern extension beyond Akron has not been surveyed. But enough is known to mark the boundary in the Erie basin; and here we find the counterpart of the Algonquin beach, of the basins of the upper lakes, whose water plain was at substantially the same levels as the Lundy, or about 150 feet below that of the Forest beach. The Lundy water gives us the history of the lake basin between the Warren episode and the nativity of Lake Erie.

After the Lundy rest, the waters were gradually drained to lower levels, until they were held in the Erie basin by a Devonian limestone escarpment, rising 20 or 30 feet above the present outlet of Erie. The remains of another rocky barrier, of 40 feet, now occurs over a mile north of the present site of Niagara Falls. The country between these ridges is low, so that there were pond-like expansions of the Niagara until a recent date, when the falls cut through this William

Johnson* ridge. Below this ridge, for six miles to the brow of the escarpment, the Niagara River drained the Erie waters; and boats might have sailed from lake to lake. The waters in the Ontario basin did not pause long at this high level, but gradually sank to the Iroquois plain 300 feet below the plain of Lundy beach. The Iroquois beach marks a long rest during which the early Niagara cascaded only 200 feet from the upper to the lower lake, and Erie formed only the lakelet as shown on the map.

Upon the dismemberment of Warren water, the Algonquin basin emptied its waters, at first through a strait by way of Lake Nipissing, and later by a river in the same region into the Ottawa valley. There was no connection between the Huron basin and the Erie until after the terrestrial deformation following the Iroquois episode. Then the Huron waters overflowed the southern rim of its basin and emptied into the youthful Lake Erie. The outlet of the Erie basin was also raised so that the plains at the head of its basin were flooded. This tilting has continued until the beach in the vicinity of the falls is now raised about 160 feet above its submerged extension near Point Pelée. Of this amount of tilting, only 46 feet have contributed to the ponding back of the waters so that the lake now extends to Toledo. The deformation of the Lundy beach in the Niagara district amounts to 2·5 feet per mile in direction N. 10°–15° E. More detailed measurements† may possibly show that the warping may reach nearly 3 feet per mile. The deformation of the Iroquois beach, which is newer than the Lundy strand, amounts to somewhat more than 2 feet per mile north of the mouth of the Niagara.

Had the falls receded past the Johnson ridge before the deformation of the region had reached the present amount, the Erie drainage would have been turned into the Mississippi at Chicago, just as the warping has changed the direction of the outlet of Lake Huron from the Ottawa to the St. Clair River. This brings us to the first possible computation of the rate of terrestrial deformation of the old shore of the lake region.

A rise of 7 feet in the level of Lake Michigan would send the waters of that lake over the rocky divide to the Mississippi. A rise of 16 feet in the Erie level would effect the same result; but the silt covering this rocky floor rises 3 or 5 feet higher and the Johnson ridge has been raised so that the deserted banks indicating the old surface of the Niagara river are now

* Named after Sir William Johnson who took possession of the falls about 1760.

† Some of these measurements were barometric from adjacent known levels, and consequently closer calculations were useless.

40 feet above the Erie level. Thus it becomes apparent that the elevation of about the last 20 feet has taken place since the recession of the falls past the Johnson ridge, for otherwise such a large river with a great breadth would have emptied the lakes and the recession of the falls must have ceased. That the water was recently higher about the head of Lake Michigan than now, the swampy flats bear witness, and the low lands continue far southward so that the rocky floor of the country—only 7 feet above the lake level (Ossian Guthrie) is 25 miles distant from the lake. Over this extensive plain, the low country has been a swamp, and drained sluggishly in both directions whilst silting over, to the extent of a few feet, the rocky floor of the country. But the entire drainage of Lake Michigan to the southwest could not have been established. The lowering of the water by a few feet in the Michigan basin as well as in the Erie has been produced by the recession of the falls past the Johnson ridge.

From the modern rate of the recession of the falls, which is about four feet a year, and the distance of 6,000 feet which the falls have receded, since passing the Johnson ridge, we find that the terrestrial warping in the vicinity of Niagara Falls could not have exceeded 24 feet in 1500 years, or 1·5 feet a century. But with the silting up of the Chicago (more correctly Lemont) overflow not more than 20 feet (or possibly 15 feet if the waters were deeper) of the last uplift of the Johnson ridge have been developed since the recession of the falls through that ridge. Thus the rate of terrestrial deformation or uplift in the Niagara district does not exceed 1·25 a century, with a possible reduction to one foot in the same time, if the secular rate were uniform. But there have doubtless been episodes of rest and others of uplift so that the actual rate of movement might have been more rapid, but the above estimate is the average during these times of elevation and intervening repose.

The agents of the deformation in the Erie basin have not been so continuous or so active as in other portions of the lake region; but if a mean rate for long epochs can be taken as here indicated, then nearly 13,000 years* have elapsed since the Lundy beach commenced to be deformed. The Iroquois beach is however more accurately measured. In the vicinity of the outlet of Lake Ontario, the deformation is double that in the Niagara district. At that outlet, the tilting has amounted to 370 feet by the post-Iroquois movement, and at 2·5 feet a century about 14,800 years have elapsed since the close of the episode of the formation of that deserted shore line. The conjectural mean deformation over long epochs

* 160 feet divided by 1 to 1·25 feet a century.

closely accords with our best estimates of the age of the falls, which will make another chapter in the lake history.

The inferred rate of terrestrial deformation in the Niagara district is 1·25 feet a century; 2·5 feet at the outlet of Lake Ontario; and 2 feet northeast of Lake Huron. These figures may be of use in reading the future of Lake Erie.

Applied to the Erie basin, the indicated deformation continuing, it appears that before Niagara Falls can have receded past the Devonian ridge near Buffalo,* the drainage of the upper lakes will have been turned into the Mississippi Valley, just as the Huron waters have been turned from the old Nipissing channel and Ottawa River to cascade over the falls; and thus may require 7,000 or 8,000 years. In this case the future life of the lakes will be very long; as their drainage will only be effected by the excavation of a deep valley backward from the Mississippi River into the lake basins.

ART. XX. — *On the Crystallization of Enargite;* by L. V. PIRSSON.

THE crystal form of enargite, the cuprous sulpharsenate Cu_3AsS_4, was first described by Dauber† from Peruvian specimens in the Krantz collection presented by Breithaupt the discoverer. Dauber gives only a basal projection of the forms noted by him. Also crystals from Brixlegg in Tyrol have been described by Zepharovich;‡ from the Serra Famatina in Argentina by vom Rath§ and from Luzon by Zettler as mentioned by vom Rath.‖ None of these authors give any figures of the crystals observed by them except that vom Rath gives a basal projection of trillings from the Serra Famatina.

It has been thought therefore that a description of some American occurrences accompanied by figures would be useful and not without interest.

Among a suite of eruptive rocks sent to Prof. Dana by Mr. R. C. Hills and collected in the Summit District, Colorado, is a series taken from the Ida Mine which presents in an extremely interesting way, as shown in an accompanying note by Mr. Hills, the method of deposition of enargite at this locality. It occurs in a porphyry containing large phenocrysts of orthoclase often nearly an inch in diameter. By hot solutions these

* These estimates will be more fully explained in a forthcoming paper upon the history of Niagara Falls.

† Pogg. Ann., xcii, p. 237, 1854.

‡ Zeit. Kryst., iii, p. 600, 1879.

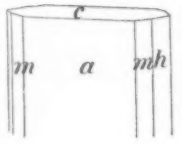
§ Zeit. Kryst., iv, 426, 1880.

‖ Jahrb. Min., i, p. 159, ref. 1880.

have been kaolinized and often entirely removed; the enargite, frequently accompanied by free gold, being deposited as a secondary process in the cavities thus formed. The groundmass of the porphyry retains to a considerable extent the form of the feldspar phenocryst and the masses of enargite are thus pseudomorphous in shape.

While generally in compact masses or with the crystals so crowded as to be indistinct, at times the cavities are lined by small glittering prisms of a bluish black color, in size up to three mm. in length. They are very tabular from a large extension of the macropinacoid $i\text{-}\bar{i}$ (100) and appear as in fig. 1, being composed of the following simple forms a, $i\text{-}\bar{i}$ (100); c, O (001); m, I (110) and h, $i\text{-}\bar{2}$ (120). The forms were identified by the following measurements.

Fig. 1.



	Calc.	Meas.	
$h \wedge m$ $(110 \wedge 1\bar{1}0)$	$= 82°\ 7'$	$81°\ 22'$	$81°\ 37'$
$m \wedge h$ $(120 \wedge \bar{1}20)$	$= 59\ 43$	$59\ 55$	$60\ 16$

In these, as in the following in this article, the calculated angles are derived from the fundamental angles assumed by Dauber in which $(110) \wedge (1\bar{1}0) = 82°\ 7\frac{1}{2}'$ and $(001) \wedge (011) = 39°\ 31'$ the axial ratios derived from these being

$$\dot{a} : \bar{b} : \dot{c} :: 0{\cdot}8712 :: 1 : 0{\cdot}8248$$

The prisms of these enargite crystals are strongly striated in a vertical direction, which accounts for the deviation in the calculated and measured angles. The base is not striated, but is rough and does not reflect light well.

Enargite from various American localities has been analyzed and described by several authors. These may be briefly mentioned as follows:

Brewer's Mine, Chesterfield, South Carolina, analyzed by Genth.* Willis Gulch near Black Hawk, Colorado. Described by Burton.† Morning Star Mine, Monitor District, Alpine Co., California. Analyzed by Root.‡ Tintic District, Utah, described by Silliman,§ where it occurs at several mines, material from the Shoebridge Mine having been analyzed by E. S. Dana.‖

No crystals are mentioned as being suitable for crystallographic work, the various authors describing the material from

* This Journal. II, vol. xxiii, p. 420, 1857.
† This Journal, II, vol. xlv, p. 34, 1868.
‡ This Journal, II, vol. xlvi, p. 201, 1868.
§ This Journal, III, vol. vi, p. 126, 1873.
‖ Op. cit.

these localities as either massive, or in rude columnar structure with cleavage surfaces or those of striated prisms, and this is confirmed by an excellent suite of specimens from the above occurrences in the Brush collection.

More recently enargite in considerable quantities has been discovered in various places in Colorado; and that from the mines at Red Mountain, especially, furnishes material suitable for crystallographic investigation. A very fine suite of specimens from the National Belle Mine was collected by Prof. S. L. Penfield during the summer of 1891, while engaged in work for the U. S. Geological Survey. For the purpose of carrying out the present investigation he has kindly placed these specimens at the disposal of the author, who takes this opportunity of expressing his thanks for the free use of the material.

The mineral, which is here mined for silver and copper, occurs in vertical shafts or "chimneys" in a decomposed volcanic rock. It generally occurs accompanied by pyrite and is in large cleavable masses, rarely in distinct crystals. When crystallized it is usually in thick striated prisms up to two or three mm. in length and of the habit shown in fig. 2, consisting

Fig. 2.

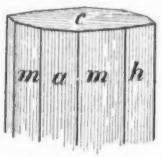


Fig. 3.

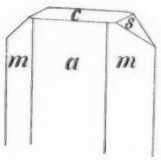
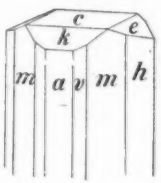


Fig. 4.



of the simple forms c, O (001); a, $i\text{-}\bar{i}$ (100); m, I (110) and h, $i\text{-}\breve{2}$ (120). In some specimens the faces are more even and the unit brachydome s. $1\text{-}\breve{i}$ (011) appears as shown in fig. 3. On one specimen crystals were present which showed the unit macrodome k, $1\text{-}\bar{i}$ (101) and in addition a prominent and well defined brachydome was seen. This was invariably so rough, from small pit-like markings and minute octahedra of pyrite that only an approximate measurement of it could be made. Measured on the base it gave an angle of 25° while $012 \wedge 001$ requires 22° 25′. It is therefore regarded as being most probably the $\frac{1}{2}$ brachydome. Besides the planes already mentioned these crystals showed the macroprism v, $i\text{-}\bar{2}$ (210) and their habit is represented in fig. 4.

Another very common habit, from this locality, is a flat tabular one, both bases being present and the crystal is attached by one end of the macro-axis. This is shown in fig. 5. The

most interesting crystals which have been observed among these specimens however are represented in fig. 6. They are

Fig. 5.

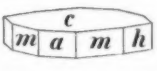


Fig. 6.

rather thick tabular in habit and attached by one end of the macro-axis like those just described. They consist of the planes *c*, *O* (001); *a*, *i*-$\breve{i}$ (100); *m*, *I* (110); *l*, *i*-$\breve{3}$ (130); *s*, 1-$\breve{i}$ (011) and *z*, $\frac{3}{4}$-$\breve{3}$ (134). The planes of 130 are dull and do not reflect light well, while the other prisms are extremely brilliant, giving a good reflection of the signal, as do also the dome 1-$\breve{i}$ (011) and the brachy-pyramids $\frac{3}{4}$-$\breve{3}$ (134). It was noticed on these crystals, of which several good examples were examined, that the dome and brachy-pyramid always appeared only at one end of the prism, the other being simply cut off by the base (00$\bar{1}$). Moreover the upper base (001) is apt to be dull and not to reflect light well, while the lower one (00$\bar{1}$) is very brilliant and striated by oscillation with the unit macro-dome (101). These facts would seem to point toward the species being hemimorphic. Of the forms observed upon these crystals the following are new to the species *e*, $\frac{1}{2}$-$\breve{i}$ (012); *v*, *i*-$\bar{2}$ (210) and *z*, $\frac{3}{4}$-$\breve{3}$ (134). The following table gives the calculated and measured angles by which the forms were identified.

Planes.	Calc.	Meas.
$m \wedge m$, 110 ∧ 1$\bar{1}$0	82° 07½′	82° 3′, 82° 17′, 82° 04′
$a \wedge h$, 100 ∧ 120	60 8½	60 3, 60 20, 59 45
$a \wedge v$, 100 ∧ 210	23 12	23 13, 23 18
$m \wedge v$, 110 ∧ 210	17 31	17 28, 17 42, 17 19
$m \wedge l$, 110 ∧ 130	28 0	28 24
$c \wedge k$, 001 ∧ 101	43 26¼	43 01
$c \wedge s$, 001 ∧ 011	39 31	39 39, 39 10
$s \wedge z$, 011 ∧ 1$\bar{3}$4	13 45¼	13 45, 13 49
$z \wedge z$, 134 ∧ $\bar{1}$34	22 45¾	22 46
$c \wedge z$, 001 ∧ 134	33 31	33 33, 33 40

The form $\frac{3}{4}$-$\breve{3}$ (134) was also identified by being in the zones *c* (001) ∧ *l* (130) and *m* ($\bar{1}$10) ∧ *s* (011) which have probably influenced its appearance.

The powder of these crystals tested in the open tube gives abundant reaction for arsenic and none for antimony, from which we may conclude that they are very pure enargite, not more than a trace at most of famatinite, the isomorphous antimony compound Cu_3SbS_4, being present.

Mineralogical-Petrographical Laboratory.
Sheffield Scientific School, New Haven, November, 1893.

ART. XXI.—*Relations of the Lower Menominee and Lower Marquette Series in Michigan (Preliminary)*; by HENRY LLOYD SMYTH.

NEARLY all writers on Michigan geology from Brooks to Wadsworth have maintained the general equivalence of the Marquette and Menominee iron-bearing series.*

This opinion has been founded on the similar unconformable relations of the two series to an undoubtedly older crystalline complex, and on a general lithological similarity between some of the individual members.

It is the object of this paper to review briefly the evidence by which this correlation has been supported, and to present some new facts that appear both to modify and to give it a more definite shape. It should be remembered that the rocks of the two series have never been traced into each other, and that until recently there has been an unbridged gap many miles wide between them.

General Relations.

So long as the iron-bearing rocks of Michigan were thought to constitute an uninterrupted succession, the argument from similar relations to similar older rocks had much force. It was further strengthened by Van Hise's discovery that the Marquette series was divided into two unconformable series, and by his later announcement, that the Menominee series was probably similarly divided by an unconformity. More recent and extended work in the northern extension of the Menominee area has so far confirmed these views that it is now certain that the Menominee rocks are made up of an upper and a lower series, separated by an unconformity.

The general relations in the two districts are given in the table below, which differs from that given by Van Hise in Bull. 86, U. S. G. S., in the substitution of Upper and Lower Menominee for Western Menominee, and Menominee Proper.

* In order not to re-state views that are already so well known, the reader is referred to the following list, which does not pretend to be exhaustive as regards either authors or titles:

Brooks, Geol. Wisconsin, vol. iii, p. 450 table.—Gredner, quoted in Bull. 86, U. S. Geol. Survey, p. 90.—Irving. 7th Ann. Rep. U. S. Geol. Survey, p. 435.—Van Hise, Bull. 86, U. S. Geol. Survey, pp 197-8.—Wadsworth, Report State Board of Geol. Survey, Lansing, Mich., 1893, pp. 104, 117.

Marquette District.	Menominee District.
Upper Marquette.	Upper Menominee.
Unconformity.	Unconformity.
Lower Marquette.	Lower Menominee.
Unconformity.	Unconformity.
Archæan.	Archæan.

This undoubtedly constitutes a strong chain. The weak point as Van Hise has fully recognized is that neither of the sedimentary series of the one district has been traced into the corresponding series of the other. Consequently to correlate the two series of the one with the two series of the other, involves the assumption that the two time-breaks extend over both districts, and mean the same thing in each.

Lithological Characteristics.

Before considering the lithological similarities of the individual formations, it is first necessary briefly to recall the characteristics of, and the order of succession in, the lower series of the two districts.

Lower Menominee.

Avoiding minute subdivision the lower Menominee consists of

(1) A basal quartzite, rarely conglomeratic. The thickness may reach a maximum of about 1000 feet, and over large areas is at least 700 feet.

(2) A crystalline limestone which averages about 700–1000 feet in thickness. On the Fence River in T's 44 and 45 N. R. 31 W., where it largely if not entirely replaces the lower quartzite, the thickness attained, if there are no subordinate folds, is from 1500–2000 feet.

(3) Red, black and green slates, that are not known to exceed 200–300 feet in thickness. The slates here and there contain the iron formation that affords the rich ores of Iron Mountain and Norway. In the southern part of T. 44 N., R. 31 W., the horizon of the slates is in part occupied by altered eruptives, that rapidly increase in thickness towards the north, the whole attaining a maximum of nearly 2000 feet on the Fence River in T. 45 N., R. 31 W.

(4) The highest member, except volcanics, yet recognized in the Felch Mountain and Fence River divisions of the Lower Menominee is typically developed at Michigamme Mountain, S. 4, T. 43 N., R. 31 W. and S. 33, T. 44 N., R. 31 W., and has been called the Michigamme jasper. This is a greatly altered ferruginous rock usually carrying apparently fragmental quartz grains. Various stages in the alteration permit two or three

types to be recognized. The least modified seems to indicate that the rock was originally in part at least a clastic sediment. The alteration appears to have been effected by the infiltration of iron salts, the formation of cherty silica, and the replacement of the original constituents to varying degrees. The most highly altered type bears the closest possible resemblance in the hand specimen to the banded specular jasper seen on the Republic bluff.

Iron ores occur at three horizons in the lower Menominee. The lowest and least important is found in the upper portion of the quartzite near its junction with the limestone. While lean (usually martite) ores are of wide distribution, only one workable deposit of rich ore has as yet been discovered in this position in the series. The slate member contains the great majority of the rich ore deposits. These occur as local concentrations in a ferruginous rock, composed of banded jasper and iron ore, which perhaps is the modified representative of portions of the slates carrying a large proportion of non-clastic material of original deposition. The banded jasper is not continuous, and it occurs at different horizons in the slates. The third horizon is the Michigamme jasper, which up to the present time has yielded only a few small bodies of rich ore.

Lower Marquette.

The lower Marquette series in the western part of the Marquette area, where it most nearly approaches the Menominee region consists, when exposed, of

(1) A basal conglomerate—quartzite—quartz schist, probably less than 100 feet thick. North of the Michigamme Mine the quartzite passes upward into a slate.

(2) An iron-bearing formation which may be divided further into a lower member, composed of actinolite (or gruenerite),* magnetite, and silica, one or two of which may locally predominate over the rest, and an upper member, usually but not invariably, characterized by bands of red jasper and specular hematite. The iron-bearing member has a maximum thickness of more than 1000 feet, but usually it has been cut down greatly or, with the lower quartzite, entirely, by the Animikie† transgression.

The Marquette iron ores, except those in the Upper Marquette series, occur, as Van Hise has shown,‡ either (*a*) at the

* A. C. Lane and F. F. Sharpless, this Journal, Dec., 1891, p. 505. Report of the State Board of Geol. Survey, Michigan, Lansing, 1893, p. 183.

† Animikie is here used as a general term, covering the time of deposition of the Upper Huronian, Upper Marquette, Upper Menominee, Penokee-Gogebic, and the Animikie of Northern Minnesota and Canada, all of which are regarded as generally equivalent.

‡ This Journal, Feb., 1892.

contact of the lower iron bearing member with the upper quartzite, when the ore may be either a concentration in the lower iron-bearing member, or a detrital member of the upper series, or (*b*) more rarely, entirely within the iron-bearing member of the lower series.

These descriptions are expressed briefly in the following table, in which the members of the two series are shown in parallel columns for lithological comparison.

Menominee.	Marquette.	
Michigamme Jasper.	Jasper banded with ore.	Iron formation.
Slates (Principal iron formation.)	Magnetite-Actinolite Schist.	Iron formation.
Limestone.	Quartzite.	
Quartzite.		
Archæan.	Archæan.	

It will be seen that the lithological resemblances are these: (1) Each series has a similar quartzite at its base. (2) Each contains iron-bearing formations. Neither is a safe basis for correlation in the absence of direct stratigraphical evidence, for not only has nearly every positive movement throughout geological time been marked by a basal sandstone or quartzite, but the undoubted general resemblance between the iron-bearing formations of the two districts is not closer than that between either and like formations of Animikie age.

On the other hand the lithological differences, and especially the absence from the Marquette column of the Menominee limestones and slates, are very striking. It is on this point that recent work furnishes some positive, though not conclusive evidence.

Structure and Distribution.

The Menominee rocks, as will appear in detail in a forthcoming report, have been traced from Michigamme Mountain with a north and south strike, north through T's 44 and 45 N., R. 31 W. In these townships they lie, with an easterly dip, on the eastern side of a structural axis, along which granite-gneisses outcrop in the western part of T's 44 and 45 N., R. 31 W., and in the eastern part of T's 44 and 45 N., R. 32 W. It has been possible to follow the Michigamme jasper carefully and closely by means of its magnetic properties. In the middle of T. 45 N., R. 31 W., where the rock is next found in exposures and explorations, it is seen to have somewhat changed in character. The lower portion has become decidedly quartzitic, containing, however, gashes and films of specular hematite. The upper portion is finely banded, and

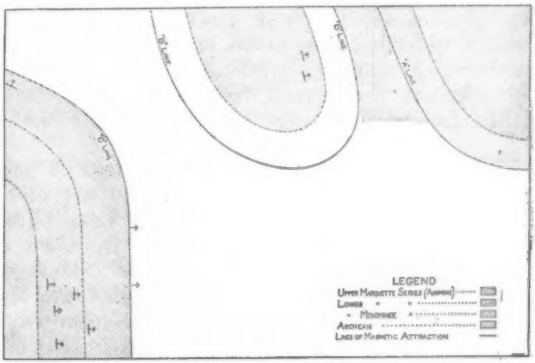
contains actinolite, magnetite and dark chert. This is the portion of the formation that most disturbs the needle. While thin sections of this rock have not yet been examined, the constituent minerals are evidently not so distinctly segregated as is usual in the Marquette actinolite schists. Otherwise the rocks bear considerable resemblance to each other.

The lower iron-bearing rocks of the western Marquette district have been traced southward from the northwestern end of the Republic tongue, for a long distance. Coinciding with the lower portion of the iron-bearing member, or the magnetite actinolite schist, is a very strong and continuous line of magnetic attraction which was first followed for part of the distance by Major Brooks over 20 years ago. This line of attraction is proved to coincide with the magnetite actinolite schist member by occasional outcrops and by explorations at considerable intervals. East of it is a granite area, and between the two, the lower quartzite outcrops near the northern end of the Republic tongue. Farther south the quartzite is presumably present, but no outcrops have been found in the heavily drift-covered country. This line of attraction may be called the A line. Less than half a mile west of the A line a second line of magnetic attraction runs parallel to it for a considerable distance, which may be called the B line. This B line has been traced completely round an oval area in which granite and gneisses have been discovered in three sections. These gneisses lie east of the axis of the enclosed oval, and strike parallel to the B line and dip towards the east. Throughout the 20 miles or more through which the B line has been followed no outcrops of any kind have been found upon it. That it does, however, represent a belt of magnetic rock entirely enclosing an Archæan area admits of no possible doubt. Explorations along the A line have established the fact that the geological succession in going from east to west across it is from older to younger formations. That is, the dip is towards the west. The gneisses in the oval enclosed by the B line dip toward the east on the east side of the axis of the oval. This, coupled with the fact that both the A and B lines, in the one case partially, in the other completely, encircle domes of Archæan rocks, makes it certain that the rocks which they represent dip towards each other. In other words, in that part of their course in which they run parallel they occur on opposite limbs of a synclinal fold. Moreover the space between them is known by exposures and exploration to contain upper Marquette quartzite and mica schists.

This occurrence of the A line on one side, and of the B line on the other, of a long and very narrow synclinal fold, together with the entirely similar general relations of each to

enclosed Archæan areas, hardly leaves room for doubt that they represent the upturned edges of one and the same formation. Furthermore, no other rock is known in the region that is at once so strongly and so uniformly magnetic. The conclusion therefore is, that the B line like the A represents the lower Marquette actinolite schist.

It has already been shown that the Michigamme jasper, a magnetic rock, can be traced north from Michigamme Mountain, by its magnetic properties, and that when next exposed it has been partly differentiated into a lower quartzite member and an upper member, which alone disturbs the needle, containing magnetite and actinolite. Also, that it overlies conformably an easterly dipping succession, made up below it of nearly 2000 feet of highly altered eruptives and nearly 2000 feet of limestone, the whole resting upon Archæan gneisses, to the west. The magnetic line that marks the upper portion of the Michigamme jasper may be called the C line. For $2\frac{1}{2}$ miles in the northern part of its course the C line runs nearly parallel with, and from $1\frac{1}{2}$ to 2 miles west of the B line, where the latter circles round the southwest quarter of its enclosed Archæan oval. This distance of less than two miles, is the interval that now separates the lower Menominee series from the lower Marquette series. A sketch showing the relations in this interesting region is given below.



The area between the B and C lines is covered and shows no magnetic disturbances. The rock of the C line dips towards the east, that of the B line, in the portion nearest the C line must dip towards the west. They lie then on opposite sides of a trough, and probably are one and the same formation.

If they are not, then the C line has no magnetic representative on the eastern, nor the B line on the western limb of the fold. The probability is moreover strengthened by the lithological affinities of the upper portion of the Michigamme jasper,—the C line rock,—in some phases, to the lower Marquette magnetite actinolite schist, in others, to the specular jasper.

If then these two rocks are regarded as equivalents, the lower Marquette quartzite may, with nearly equal probability, be taken to represent the lower quartzite portion of the C line formation. The whole of the lower Marquette series would thus be represented by the highest member of the lower Menominee. What then becomes in the Marquette district of the great thickness of limestone, quartzite and eruptives which lie below the Michigamme jasper in the Menominee, and how is its absence to be accounted for?

The most probable explanation is that the pre-Algonkian basement sank continuously in both districts, but that the Marquette was initially the more elevated, and as a whole was dry land while the lower quartzite, limestone and slates were going down in the Menominee. The transgressive movement from the south reached it when the lower portion of the Michigamme jasper was being deposited. On this view the lower Marquette quartzite would generally represent the lower quartzite horizon of the Michigamme jasper. But in going from the more distant areas of lower Marquette rocks toward the lower Menominee the base would gradually become the equivalent of older horizons in the latter until it passed finally into the lower Menominee quartzite. The absence of the lower Menominee formations from the Marquette district would thus be explained by overlap of the Michigamme jasper.

The Mt. Mesnard series of quartzite, limestone and slates, as described by Wadsworth,* in the eastern part of the Marquette area, between the Cascade range and Lake Superior has many points of resemblance to that part of the lower Menominee series below the Michigamme jasper. Its age is still in doubt, but if it should prove to underlie the lower Marquette (Wadsworth's Republic Formation), its position would probably indicate the limit of the old Marquette highland on the eastern side.

Conclusion.

The views here presented are based in part on fact, and in part on inference, and it is desirable in conclusion clearly

* Report of the State Board of Geol. Survey, Michigan, Lansing, 1893. Wadsworth is inclined to regard it as of upper Marquette age.

to distinguish the one from the other. The three magnetic lines, A, B and C, and the connection of two of them, the A and the C, with characteristic and similar rocks, are facts not to be doubted. Nor is it any less clear that the rocks of the A and B lines, and of the B and C lines dip toward each other in the respective spaces between them. There is no positive evidence as to the nature of the B line rock, for no one has ever seen it. Therefore the conclusion that the three lines represent the same rock is an inference which underground exploration may prove to be erroneous. All that can now be said is that of the five possible hypotheses of equivalence or non-equivalence between the A, B and C rocks, that of equivalence is by far the most probable.

Assuming equivalence the evidence points then to these conclusions:

(1) The lower Menominee quartzite limestone and slates are all older than any formation in the Marquette area.

(2) The Michigamme jasper was deposited in a continuous sheet over both districts, and in the Marquette constitutes both the iron-bearing formation and, for most of the area, the lower quartzite.

(3) The principal ore horizon of the Menominee has no equivalent in the Marquette district.

Cambridge, Mass., Nov. 21, 1893.

ART. XXII. — *Six and Seven Day Weather Periods;* by H. HELM CLAYTON.

THERE is a seven day period in the weather, so noticeable at times in the United States, that it has embodied itself in such popular sayings as, "If it rains on the first Sunday of a month it will rain every Sunday," etc.

In regard to this period, as early as 1858, Prof. Joseph Henry, Director of the Smithsonian Institute, wrote: . . . . "Most persons can remember the occurrence in succession of a series of storms on Sundays. In one case we recollect this to have taken place six times in succession. There is nothing in this particular day to induce the occurrence of a storm, but merely it will be more likely to be remembered when it happens at this time; and although the interval may not be precisely seven days, yet it may differ so little from this that a part of the first and sixth Sundays may be included in the cycles of disturbance." See Patent Office Report, 1858, page 490.

In a work on The Atmospheric System Developed (1870) by Thomas B. Butler is found the following: "It is doubtless within the recollection and experience of every one who has

lived long, that at a remembered period some particular day in the week, for several weeks, was stormy; sometimes with, and at other times without an intervening storm, or showery condition, on some day in the week."

In Vennor's Weather Almanac for 1883, p. 13, it is stated: "We find closely corresponding weather periods have frequently occurred in seven, fourteen, and twenty-one year divisions of time, and most of us are familiar with the every seventh storm day of our winter and summer months. Only as recently as last autumn (1881) the general remark was that every Saturday stormed; and it will be of further interest to the public to learn that these stormy Saturdays lasted through a period of just about seven weeks."

The fact that this period was independently discovered by the present writer, without any knowledge of its previous observation, may perhaps be taken as additional proof of its existence.

The widespread and tenacious belief in a connection between the changes of the moon and the changes in the weather probably arose from the popular observation of the seven day weather cycle which agrees so approximately in length with the mean interval between the phases of the moon.

In the American Meteorological Journal for August, 1885, p. 162, the writer gave a marked example of this seven day period in which the temperature and weather at several widely separated stations in the United States oscillated with almost perfect regularity for six or seven weeks in succession. Moreover, the oscillations were not simultaneous at all the stations, but due to barometric minima which moved from west to east at the normal rate of American storms. It was stated by the writer that he had followed this seven day period for several years, and found that at intervals it rose to considerable prominence, then decreased in intensity and apparently died out. He also stated that "there seems to be an oscillation of about three days which acts in a similar manner." Later this was called a six day period on account of its similarity to the seven day period, as will be seen from what follows.

In 1887 the trustees of the Elizabeth Thompson fund granted the writer a part of the fund for further research on this subject; but he was unable to undertake it at that time. In January, 1893, however, his attention was again called to this subject by noticing a marked regularity in the oscillations of the temperature at Blue Hill Observatory; and in the American Meteorological Journal for May, 1893, he showed that all the temperature maxima at the Observatory during 1891 and 1892 could be arranged so as to follow each other at approximate intervals of six or seven days, or half these intervals, and the regularity of the sequences was much greater

than could be attributed to chance. It was further shown that intervals of six, or three days, would prevail for awhile and then the sequence would break, and intervals of seven, or three and a half, days would follow. Furthermore, it was found that the changes from intervals of one length to that of another were separated by intervals of twenty-seven days, or some multiple of this number, a period which agrees very closely with the length of a solar rotation.

For a further study of these periodicities, Mr. Fergusson, the assistant observer at Blue Hill Observatory, furnished the writer with the dates and hours of all the barometric minima recorded by the barograph at the Observatory since its establishment in 1885.

In this data were found many instances of six and seven day periodicities lasting several weeks, and sufficiently striking to be easily recognized. A few of these are here given as illustrations:

The Dates and Hours of occurrence of barometric minima at Blue Hill Observatory—lon. 71° W., lat. 42° N.

Showing 7 day intervals.

1886.		Interval. d.	hr.
April	6, 6 P. M.		
		7	−1
"	13, 5 P. M.	7	+33
"	22, 2 A. M.	7	−12
"	28, 2 P. M.	7	+2
May	5, 4 P. M.	7	+22
"	13, 2 P. M.	7	+3
"	20, 5 P. M.	7	+6
"	27, 11 P. M.	7	−10
June	3, 1 P. M.	7	−3
"	10, 4 P. M.	7	+7
"	17, 11 P. M.	7	+40
"	26, 3 P. M.	7	−12
July	3, 3 A. M.		
Means,		7	+6·3
Mean Departure,			±13

1888.		Interval. d.	hr.
Oct.	2, 4 A. M.		
		7	−15
"	8, 1 P. M.	7	+50
"	17, 3 P. M.	7	−4
"	24, 11 A. M.	7	−4
"	31, 7 A. M.	7	−6
Nov.	7, 1 A. M.	7	+43
"	15, 8 P. M.	7	−15
"	22, 5 A. M.	7	+10
"	29, 3 P. M.	7	−10
Dec.	6, 5 A. M.	7	+20
"	14, 1 A. M.	7	+15
"	21, 4 P. M.		
		7	+7·5
			±18

1891.		Interval. d.	hr.
April	12, 4 A. M.		
		7	+11
"	19, 3 P. M.	7	+46
"	28, 1 P. M.	7	−21
May	4, 4 P. M.	7	+1
"	11, 5 P. M.	7	−1
"	18, 4 P. M.	7	+24
"	26, 4 P. M.	7	+0
June	2, 4 P. M.	7	+1
"	9, 5 P. M.	7	+0
"	16, 5 P. M.	7	−12
"	23, 5 A. M.		
July	---- ----	7	+17
		7	+17
"	8, 3 P. M.		
"	15, 3 P. M.	7	+0
		7	+6·4
			±11

Showing 6 day intervals.

1886.		Interval. d.	hr.
Oct.	6, 5 P. M.		
		6	+6
"	12, 11 P. M.	6	−4
"	18, 3 A. M.	6	+1
"	24, 4 A. M.	6	+34
"	31, 2 P. M.	6	+16
Nov.	7, 6 A. M.	6	+10
"	13, 4 P. M.	6	+22
"	18, 2 P. M.	6	−31
"	25, 2 P. M.	6	−20
Dec.	1, 1 A. M.	6	+15
"	7, 4 P. M.	6	+11
"	14, 3 A. M.		
Means,		6	+5·3
Mean Departure,			±14

1887.		Interval. d.	hr.
Jan.	6, 7 A. M.		
		6	+16
"	12, 1 P. M.	6	−16
"	17, 9 P. M.	6	+18
"	24, 3 P. M.	6	+6
"	30, 9 P. M.	6	+21
Feb.	6, 6 P. M.	6	−22
"	11, 8 P. M.	6	+25
"	18, 9 P. M.	6	−7
"	24, 2 P. M.	6	+5
March	2, 7 P. M.		
		6	+3·8
			±13

1891.		Interval. d.	hr.
Jan.	14, 1 P. M.		
		6	+3
"	20, 4 P. M.	6	−32
"	25, 8 A. M.	6	+21
Feb.	1, 5 A. M.	6	+20
"	8, 1 A. M.	6	−11
"	13, 2 P. M.	6	+36
"	21, 2 A. M.	6	−3
"	26, 11 P. M.	6	−17
March	4, 6 A. M.	6	−5
"	10, 1 A. M.	6	+14
"	16, 3 P. M.	6	−12
"	22, 3 A. M.	6	+25
"	29, 4 A. M.		
		6	+3·3
			±16

In the preceding are given the longest series of six and seven day periods found; but in all the numerous cases the mean lengths of the periods rarely differed more than one hour from 6 days 4 hours, and 7 days 6 hours, respectively.

The next step in the investigation was to ascertain whether the end of one series was separated from the beginning of the next by even multiples of these mean intervals. This was found to be true if the series in each case were divided into two groups separated from each other about half a period, three days in one case and three and a half in the other. This discovery enabled a more exact determination of the periods to be made, and the mean lengths were found to be 7d. 6·4 hr., and 6d. 4·0 hr.

The next step was to divide the time from Jan. 1, 1885, to Aug. 31, 1893, into intervals of these lengths and ascertain whether the periods would show themselves in the average of all observations. The first investigation in this line was to count the number of times on each day of both periods that barometric minima were observed at Blue Hill Observatory. The results are shown for each interval of three years in the following tables:

Number of Barometric Minima at Blue Hill Observatory—lon. 71° W. and lat. 42° N.

On each day of the Seven day period.

	1	2	3	4	5	6	7
1885–'87,	43	38	47	**48**	40	43	**44**
1888–'90,	44	37	30	**44**	44	25	**50**
1891–'93,	34	19	31	**46**	35	35	**39**
Sum,	121	94	108	**138**	119	103	**133**

On each day of the Six day period.

	1	2	3	4	5	6
1885–'87,	34	**55**	49	40	**53**	53
1888–'90,	43	**52**	45	40	**52**	43
1891–'93,	35	**40**	37	34	**53**	41
Sum,	112	**147**	131	114	**158**	137

In both of these tables are included all the barometric minima recorded at the Observatory. Both tables show two maxima of frequency in each period which persistently remain on the same days of the periods, thus proving that the periods have definite and constant lengths; and that these lengths have been approximately determined. A close examination of the figures, however, leads to the conclusion that the mean lengths as given are not absolutely correct. Thus in the first group of the seven day period, 1885 to 1887, the maxima probably occur between the third and fourth, and the fifth and sixth days; while in the last group, 1891 to 1893, the maxima occur sharply on the fourth and seventh days, thus indicating a forward movement of the maxima of about half a day in six

years. In the six day period the figures indicate that the maxima have probably moved backward about half a day in six years. These results show that the mean length of the seven day period as given above should have been increased 0·04 hr. and the mean length of the six day period decreased about 0·03 hr.

The mean height of the barometer at Blue Hill for 8 A. M. and 8 P. M. on each day of the periods was obtained, and the results corrected for the diurnal period by subtracting 0·02 inch from the 8 A. M. means were as follows for the three years 1887, 1891, and 1893. These years were selected merely because they were most convenient for the purpose.

Mean height of the barometer at Blue Hill for each day of the Seven day period.

	1.		2.		3.		4.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887,	29 34	29·36	29 36	29·33	29·31	29·31	29·31	**29·30**
1891,	**29·32**	29·32	29 33	29·36	29·37	29·33	29·31	**29·30**
1893,	29·31	29·31	29·34	29·33	29·29	29·27	29·26	**29·25**

	5.		6.		7.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887,	29·34	29·35	29·31	29·28	**29·28**	29·30
1891,	29·33	29·36	29·36	29·36	29·35	29 35
1893,	29·30	29·30	**29·25**	29·26	29·29	29·31

Mean height of the barometer at Blue Hill for each day of the Six day period.

	1.		2.		3.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887,	29·34	29·32	29·29	**29·25**	29·28	29·31
1891,	29·34	29·33	29·33	**29·31**	29·34	29 35
1893,	29·29	29·30	29 30	**29·27**	29·29	29·31

	4.		5.		6.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887,	29·32	29·35	**29·32**	29·35	29·33	29·33
1891,	29·37	29·37	29·32	**29·30**	29·34	29·36
1893,	29·35	29·32	29·27	**29·26**	29·27	29·26

These results show very clearly the occurrence of two barometric minima in each period. The minima occur on the fourth and seventh day of the seven day period, and on the second and fifth day of the sixth day period, corresponding with the times of greatest frequency of minima previously given.

The next step in the investigation was to study the periods from the synoptic weather charts of the United States. There were two methods used, one the statistical, and the other the study of consecutive individual storms.

The average movement of storms in the United States is about 15° of longitude a day toward the east; and if the space

between 40° and 50° N. lat. be divided into intervals of this length there are formed approximate squares the sides of which are from 700 to 800 miles in length. The space between 65° and 105° W. lon. was divided up into three of these squares; and Mr. Arthur Sweetland, an assistant, counted the number of storms central in each square on each day of the six and seven day periods during the seven years 1886 to 1892, inclusive. The results are shown in the accompanying table.

The numbers of storms central between latitudes 40° and 50° N. in sections of 15° of longitude during the seven years 1886–92.

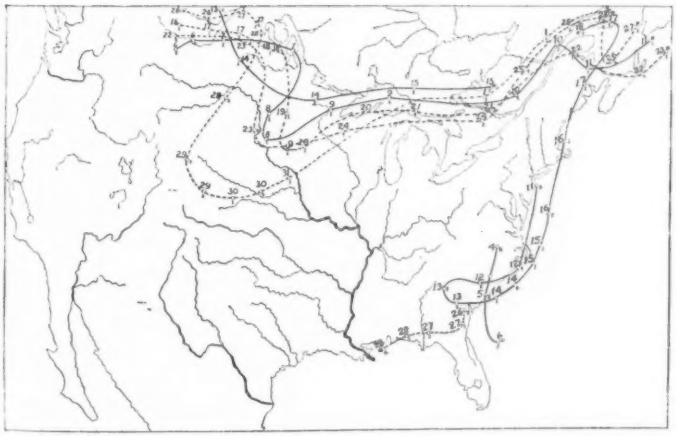
Seven Day Period.				Six Day Period.			
Day.	Long. 90°–105°	Long. 75°–90°	Long. 60°–75°	Day.	Long. 90°–105°	Long. 75°–90°	Long. 60°–75°
1	**66**	86	76	6	**68**	102	92
2	52	**98**	77	1	58	**121**	93
3	49	97	**92**	2	**69**	97	**102**
4	**58**	73	86	3	59	**103**	93
5	55	**96**	80	4	**74**	101	**105**
6	56	86	**92**	5	62	101	97
7	53	87	77				

It is seen from this table that there were two distinct maxima of frequency in each square, and the maxima occurred successively one day later for each 15° of longitude eastward. This corresponds exactly with the average eastward movements of storms in the United States, and indicates that the periodicities in question arise from a regularity in the origin and eastward drift of ordinary cyclones. When the time is separated into two intervals, namely, from 1886–1888, and 1889–1893, the same double maxima are found, and also the later occurrence of the maxima in the eastern squares. However, in the seven day period the corresponding maxima in each case occur on the average 0·46 day earlier in the interval 1886–1888 than in the interval 1889–93, showing that the length of the period used was about 0·03 hr. shorter than the true length which would be 7d. 6·43 hr. The two intervals in the case of the six day period showed that the most probable length of the period was 6d. 3·94 hrs. When the space between latitudes 30° and 40° is divided into squares corresponding with those between latitudes 40° and 50°, the chief maxima are found on the same days as in the corresponding longitude farther north, showing that the displacement of the maxima is one of longitude and not of latitude.

To study the question of periodicity in the case of succeeding individual storms, the charts of the U. S. Weather Review showing the position of the storms at 8 A. M. and 8 P. M. and the directions of their tracks were carefully examined. It was found that during intervals of about 27 days, correspond-

ing with a solar rotation, the storm tracks were found in groups, in each of which the cyclones all followed the same general direction, and were separated from each other by intervals of six or seven days, or in some cases by half these intervals.

During each interval of 27 days one of the periods alone was paramount, either the seven day or the six day, as the case might be, and this period ran through all the groups. In many of the groups the storms followed each other along such approximately parallel tracks that even the irregular bends in the tracks were the same in all. One of the 27 day intervals began during the first week in May, 1891, and the chart of storm tracks drawn by the United States Weather Bureau for that month is here reproduced as furnishing a good illustration of the phenomena under discussion. On this chart small circles show the position of the storm centers at 8 A. M. and 8 P. M., and the figures above these circles give the days of the month.



It is seen from this chart that the storms distinctly divided themselves into two groups, one beginning in British America and pursuing the usual course across the great lakes, and the other beginning near the Atlantic seaboard and taking a very unusual course toward the south. It is seen that the succeeding storms in each group followed each other so closely that the irregular bends in their tracks are approximately the same in all. But what is of especial interest here is the approximately regular interval of seven days between the succeeding storms. For example in the northern group of storm tracks,

as points which can be easily determined, take first the most southern point reached by the storms in their sudden deflection southward in the Missouri River valley, next the time of their sudden bend northward in the eastern lake region, and thirdly the most northern point reached before turning southward near the mouth of the St. Lawrence River. The observed times the storms were at these points and the times calculated from the assumption of exactly equal intervals of 7d. 6·5 hrs. were as follows:

	Observed.	Calculated.
I.	May 8, 8 P. M.	May 8, 6 P. M.
	" 14, 8 P. M.	" 15, 12 P. M.
	" 19, 8 P. M.	
	" 23, 8 P. M.	" 23, 7 A. M.
	" 30, 8 A. M.	" 30, 1 P. M.
II.	May 10, 8 A. M.	" 10, 8 A. M.
	" 15, 8 P. M.	" 17, 2 P. M.
	" 21, 8 P. M.	
	" 24, 8 P. M.	" 24, 9 P. M.
	June 1, 8 A. M.	June 1, 3 A. M.
III.	May 10, 8 P M.	May 10, 8 P. M.
	" 17, 8 P. M.	" 17, 12 P. M.
	" 22, 8 A. M.	" 25, 7 A. M.
	" 26, 8 A. M.	
	June 2, 8 A. M.	June 1, 1 P. M.

In the southern group of storms, the times of beginning, and of the most southern positions reached may be taken as points for comparing the times of occurrence of the storms with the times computed on the assumption of exact regularity in the intervals between them. The results are as follows:

Observed.	Calculated.	Observed.	Calculated.
May 4, 8 P. M.	May 4, 2 P. M.	May 6, 8 A. M.	May 6, 8 A. M.
" 11, 8 P. M.	" 11, 8 P. M.	" 13, 8 P. M.	" 13, 2 P. M.
" -- ---	" 19, 3 A. M.	" -- ---	" 20, 9 P. M.
" 26, 8 P. M.	" 26, 10 A. M.	" 28, 8 P. M.	" 28, 3 A. M.

The storm tracks arrange themselves into new groups at the end of intervals averaging slightly less than 27 days, and presumably corresponding with a solar rotation. The preceding chart gives only one of many striking instances which might be given showing the arrangement of the storms in groups, and the approximate regularity of the intervals between the storms.

Surely no one can believe all the data here presented accidental, and no unfavorable data have been suppressed. There is, however, one source of difficulty in investigating and understanding these periods, and that lies in the fact that, besides these frequent divisions of the six and seven day periods into periods of half these lengths, they are clearly associated with others of greater lengths. The shortest of

these, however, appear to be multiples of six, or seven days. In the Meteorologische Zeitschrift for February, 1886, p. 49, Magelssen has pointed out a periodicity in the temperature of about 12 days, combined with another of about 50 days. Balfour Stewart claimed the existence of a period of about 24 days (Nature, 1879–81). If these periods are arranged in sequence with the three and six day periods, there is found a geometrical progression as follows, 3, 6, 12, 24, 50.

The present writer has several times found examples in the United States of Periods in the pressure, temperature or rainfall of about 14, 21, and 30 days (American Meteorological Journal, June, 1885, p. 87; and Feb., 1886, p. 429.) Again there appears a geometrical progression as follows, $3\frac{1}{2}$, 7, 14, 21, 29 or 30.

In this way there appears to be an analogy to the phenomena of sound. The six and seven day periods may be considered the primary notes and the periods of 2, 3, 4, 5, 6, etc., times these lengths whose amplitude of oscillation decreases in proportion to their length may be considered as harmonics. The variations in the weather are made up by the variations in intensity of these components.

The causes of these periodicities are not clear; but the fact that they have definite and rigid lengths renders it almost certain that they are connected with some physical or astronomical period, or periods. The breaks in the six and seven day periods, and the redistribution of storm tracks correspond so closely with the accepted length of a solar axial rotation as to make it extremely probable that there is a connection between the two. In this case the sun may perhaps be considered in the light of a tuning fork which sets up the periodic oscillations. The same is probably true of the 11 year sunspot period.

The periodic phase of meteorological phenomena is undoubtedly complex, and much is yet to be cleared up and solved; but even the present knowledge can be used with considerable success in forecasting, as demonstrated by a practical test. See the American Meteorological Journal, February, 1886, p. 429.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Cryohydric Temperatures.*—The experiments of Guthrie on the cryohydric points of systems of mixed salts, have been repeated and the results discussed by Schreinemakers. He finds that when the two salts do not form a double salt, the cryohydric point of the mixture is lower than the cryohydric point of a solution in equilibrium with either of the salts separately. Moreover when a double salt is formed and this salt decomposes on solution, such for example as PbI_2, KI, $(H_2O)_2$, the cryohydric temperature of a solution in equilibrium with the double salt and one of its components is lower than the cryohydric temperature of a solution in equilibrium with this component alone; and the cryohydric point of a solution in equilibrium with the double salt and the component which is not deposited is lower than that of a solution in equilibrium with the double salt and the component which is deposited. Again if the double salt formed dissolves homogeneously without decomposition, as is the case for example with $CuSO_4(NH_4)_2SO_4.(H_2O)_6$, the cryohydric temperature of a solution in equilibrium with the double salt and one of its components is lower than the cryohydric temperature of a solution of the double salt alone.—*Zeitschr. Physikal. Chem.*, xii, 73, July, 1893. G. F. B.

2. *On the use of Phenanthrene as a Solvent in Cryoscopic determinations.*—In determining cryoscopically the molecular mass of indole in a naphthalene solution Garelli and Ferratini obtained anomalous results which they attributed to the formation of solid solutions of indole in the crystallizing hydrocarbon; this formation being influenced apparently by the similarity in constitution between the two. To test this hypothesis, they examined a liquid solution of carbazole in phenanthrene, and found that the crystals which separate on cooling this solution, contain a large quantity of the dissolved substance, amounting, when the solution contained 7·5 per cent of carbazole, to 11·42 per cent. Other things being equal, however, the authors regard phenanthrene a better solvent than naphthalene for use in determining molecular masses by the cryoscopic method; since its high depression constant, 120, makes it possible to obtain accurate results with very dilute solutions and its lower volatility renders it easier of manipulation.—*Gazetta Chim. Ital.*, xxiii, (1) 442; *J. Chem. Soc.*, lxiv, ii, 512, Nov. 1893. G. F. B.

3. *On the Vapor-pressures of solutions of Sulphur and Phosphorus in Carbon disulphide.*—By enclosing solutions of sulphur and of phosphorus in carbon disulphide, in a space exhausted by a Sprengel pump, and measuring the vapor-pressure by means of a manometer, Guglielmo has determined the molecular masses of these elements. At ordinary temperatures, a glass apparatus was

used, consisting of two bulbs, one to contain pure carbon disulphide, the other to hold the solution; these vessels being provided with mercury traps by which they could be isolated from each other and from the pumps. The vapor pressure of the pure carbon disulphide was first determined, then that of the solution; the ratios of the differences of the two pressures to the vapor-pressure of carbon disulphide at the corresponding temperatures being proportional therefore to the number of dissolved molecules per unit of solution. The experiments with sulphur were conducted between 0° and 13·8° and show that for solutions up to 20 per cent, the molecular depression corresponds to a sulphur molecule containing 8 atoms for the more dilute, and containing 9 atoms for the less dilute, solutions. For phosphorus the vapor-pressures were measured at 0°, several solutions being employed. The molecular depressions observed corresponded approximately to a tetratomic molecule, in the case of a 3 per cent solution; increasing somewhat as the solution was made stronger.—*Real. Accad. Lincei*, ii, 210, 1892; *J. Chem. Soc.*, lxiv, ii, 511, Nov. 1893. G. F. B.

4. *On the Influence of Heat on Chemical Reactions.*—An elaborate investigation has just been made by LEMOINE upon the influence of heat, unaffected by that of light, on the reactions which take place in aqueous solutions containing ferric chloride and oxalic acid. When these substances are present in equivalent proportions, the interaction is irreversible and proceeds according to the equation

$$(FeCl_3)_2 + H_2C_2O_4 = (FeCl)_2 + (HCl)_2 + (CO_2)_2$$

The rate at which decomposition takes place at any temperature is found to follow the well known law of mass action, which states that the amount of substance which is being decomposed at any instant is proportioned to the amount of unchanged substance contained in unit volume of the solution. The concentration remaining the same, the rate of change is found to vary markedly with variation in temperature. For example, while 0·16 of the original amount of substance was decomposed at 100°, in one hour, it was found that at ordinary temperatures only 0·019 equivalent had reacted after six years. Water accelerates the speed of change according to a law which varies slightly with the temperature. A slight excess of oxalic acid also accelerates it, but a large excess either of oxalic acid or of ferric chloride retards it; while an excess of concentrated hydrochloric almost completely arrests it. The author has studied both chemically and thermochemically the effects which these and other foreign substances have upon the course of the simple reaction and finds that they may be explained by the production of secondary reactions.—*Ann. Chim. Phys.*, VI, xxx, 289, Nov. 1893. G. F. B.

5. *Motochemistry or Stereochemistry.*—The term "motochemistry" has been proposed by MOLINARI to indicate the view that the constitution of compounds depends on the intramolecular

movements of the atoms in relation to each other, rather than on the relative positions of the atoms in space, which is the fundamental hypothesis of "stereochemistry." The new view regards the bonds by which the union of atoms is customarily represented, as signifying the nature of the swing of the atoms with relation to each other, i. e., their energy. Thus doubly linked and singly linked carbon atoms are of different value in respect to the energy of their movement with regard to each other, and double or treble bonds signify excess of energy, ready to be exerted in saturating the compound. This hypothesis the author applies to the benzene ring and shows that only one ortho-bi-substitution product is possible. Motoisomerism involves asymmetry but the term must be used in a greatly extended sense, the phenomenon depending on the mass and valence of the atoms or atomic groups as well as on their number and nature. Motoisomerides will exist in those cases in which it is possible for the order of approach of the asymmetrical carbon atom (taken in this sense) to vary toward the neighboring atoms. In the case of benzil-monoxime

$$COPh.C\begin{matrix}=N.OH\\ \diagdown C_6H_5\end{matrix}$$

for example, it is possible for two motoisomerides to exist; for if the swing between carbon and carbon be designated by *a* and that between carbon and nitrogen by *b*, these isomerides will be represented (1) by *a*, *a*, *b*, *b*, and (2) by *a*, *b*, *a*, *b*.—*J. prak. Chemie*, II, xlviii, 113; *J. Chem. Soc.*, xliv, ii, 513, Nov. 1893.

G. F. B.

6. *On the Densities of Oxygen, Hydrogen and Nitrogen.*—The densities of oxygen, hydrogen and nitrogen have been determined with great care by Lord Rayleigh. The oxygen was prepared by three different methods: (1) from chlorates, (2) from potassium permanganate and (3) by electrolysis. The air was taken from outside and was passed through potash solution, then through tubes filled with fragments of solid potash and finally over phosphoric oxide. The nitrogen was prepared by passing air through a potash solution, over reduced copper, then through a U-tube to deposit water again over heated copper and finally over heated copper oxide. The values of the densities of oxygen, nitrogen and hydrogen respectively, as compared with those obtained by other experiments, all referred to that of air as unity are given in the following table:

	Oxygen.	Nitrogen.	Hydrogen.
Regnault (corr.)	1·10562	0·97138	0·06949
v. Jolly (corr.)	1·10502	0·97245	.....
Leduc	1·1050	0·9720	0·06947
Rayleigh	1·10535	0·97209	0·06960
Mean	1·10525	0·97218	0·06952

The density of hydrogen was calculated from that of oxygen using the ratio 15·882. The mean of the best densities under standard conditions referred to water at 4° as 1000; i. e. the mass of one liter in grams, therefore, is found to be:

Air.	Oxygen.	Nitrogen.	Hydrogen.
1·29347	1·42961	1·25749	0·08991

—*Proc. Roy. Soc.*, liii, 134, 1893. G. F. B.

7. *On Free Hydroxylamine.*—An improved method of preparing free hydroxylamine has been devised by BRÜHL, which is not only safer than those heretofore used, but gives a larger yield. It is based on the reaction of hydroxylamine hydrochloride upon sodium methylate, both being dissolved in methyl alcohol; a reaction first made use of by Lobry de Bruyn. After separating the methyl alcohol solution from the precipitated salt, Brühl transfers it to a modified form of his well known apparatus for fractional distillation in vacuo, consisting of a distillation flask provided with a thermometer and an entrance tube furnished with a tap, a condenser and a multiple receiver by which a rapid change of receptacles may be made during the distillation without impairing the vacuum. The pressure in the flask is reduced to the lowest possible amount and the distillation is effected by immersing the flask in hot water. In this way and under a pressure of 22^{mm} of mercury, the hydroxylamine passes over completely at 56°–57°. The condenser is supplied with ice water and the receiver is surrounded with ice and salt; so that each drop of hydroxylamine solidifies at once as it enters the receiver; the yield being 66 per cent of the theoretical. At the temperature of 23·5° its density is 1·2044. Its refractive index for the red line of lithium is 1·4375 and for the Hγ line 1·4514. The author has proved that the constitution of hydroxylamine is $\begin{matrix}H\\H\end{matrix}\!\!>\!N-O-H$ and has shown that the molecular refraction and dispersion of the nitrogen present in it is the same as that of the nitrogen in ammonia gas and much lower than that of the nitrogen in triethylamine; the probable values of these constants of nitrogen, linked in this manner, for sodium light, being 2·495 and 0·072 respectively.—*Ber. Berl. Chem. Ges.*, xxvi, 2508, Nov. 1893. G. F. B.

8. *On a New Sulphide of Carbon.*—A new compound of sulphur and carbon, having the composition C_3S_2 has been prepared by VON LENGYEL by submitting the vapor of carbon disulphide to the action of the electric arc. The disulphide was contained in a flask and the arc carbons crossed a globe sealed above it, furnished with an upward condenser. The flask was heated on a water bath and the vapor exposed for two hours to the arc. A deep cherry red liquid remained in the flask, which was treated for a week with copper turnings to remove the free sulphur. The disulphide was then evaporated in a current of dry air and left a few cubic centimeters of a deep red liquid, possessing a powerful odor, a mere trace of which produces a copious flow of tears, ac-

companied by violent and persistent catarrh of the eyes and mucous membrane. The specific gravity of this new sulphide is 1·2739. When heated it polymerizes into a hard black substance, having the same composition. It can be partially distilled in vacuo at 60°, but even then a small portion polymerizes. In a few weeks, the liquid spontaneously changes into the black form. This form is soluble in caustic alkalies and is reprecipitated unchanged by acids. On heating it yields an inflammable gas containing sulphur which is not carbon disulphide.—*Ber. Berl. Chem. Ges.*, xxvi, 2960, January, 1894. G. F. B.

9. *Emission of Gases.*—F. PASCHEN shows that previous observers have neglected to take into account a marked absorption effect of CO_2. He finds that a 7^{cm} thick layer of this gas absorbs all the light of the wave-length of the main absorption band. The amount of CO_2 and H_2O in a 83^{cm} thick layer of the air of a room is sufficient to produce sharp absorption bands. This phenomenon is the source of error in Angström's determination of the absorption of CO_2, and apparently also in Rubens and Snow's determination of the dispersion curve of fluor spar, and in their research upon the dependence of the emission of a solid body upon the temperature. A comparison of Paschen's results with those of Angström, shows that the absorption coefficient of the latter must be doubled. CO_2 shows no absorption in the portion of the spectrum in which its absorption bands do not lie. Oxygen and nitrogen in layers a decimeter thick and under atmospheric pressure show no absorption bands. — *Ann. der Physik und Chemie*, pp. 1–39, No. 1, 1894. J. T.

10. *Apparatus for studying and showing electrical resonance.*—A. RIGHI has succeeded in obtaining electrical waves of $7{\cdot}5^{cm}$ in length. His oscillator consists of two straight brass cylinders which are terminated at both ends with spheres 4^{cm} in diameter. The entire length of the exciter with the bulb is 62^{cm}. Upon this two circular copper discs of 34·5 diameter can be adjusted. They are generally placed 43^{cm} distant from each other. Both middle spheres between which spring sparks of from 2 to 5^{mm} length, are placed in a glass vessel filled with a thick mixture of *vaselinöl* and vaseline. Opposite to the two outer spheres stand two other spheres which are connected with the poles of an electrical machine, from which the Leyden jars are removed. The resonator consists of a circle of copper wire of 57^{cm} in diameter closed by a small Geissler tube which was selected out of a large number, and was so sensitive that it lighted at a distance of 6^{m} from the exciter and so brilliantly that the interferences between electrical waves, propagation of these waves along wires, and allied phenomena could be shown to an audience. For very short waves, the exciter consisted of four brass spheres $1{\cdot}36^{cm}$ in diameter which were placed over each other. The upper and under were connected with the electrical machine, the two middle ones, capable of adjustment, were mounted in a vessel filled with a mixture of vaselinöl and vaseline. The resonators consisted of

strips of silvered glass, through the middle of which a scratch of about 0·002^{mm} breadth was made in the silver surface. This scratch served as a spark gap. An investigation was made upon the absorption of electrical waves by different substances. Ebonite, parafine and rock salt showed no absorption. Green glass, quartz-selenite and olive oil showed clearly absorption.—*Rendie, R. Acc. dei Lincei*, (5) 2, 1 Series, pp. 505–518, 1893. J. T.

II. Geology and Mineralogy.

1. *On the Devonian (Oriskany) in the Southern Appalachians;* by C. Willard Hayes, U. S. Geological Survey. (Communicated.)—In a letter written in January, 1891, concerning the Devonian rocks of the Southern Appalachians I made the following statements: "In the highly faulted region between Weisner and Indian mountains, in Alabama, are some coarse ferruginous sandstones which appear to rest directly on the Rockmart slate (presumably of Trenton or Hudson age), without any intervening rocks corresponding to the Rockwood formation further north. Fossils have been collected in this ferruginous sandstone concerning which Mr. Walcott in a letter to Mr. Russell says: 'The fossils collected by Mr. Cooper Curtice in a sandstone on the side of Frog Mountain, Ala., include *Zaphrentis* sp.?, *Chaetetes complanata?*, *Spirifera arenosa?*, *S. arrecta?*, *Pterinea?* sp.?, *Platyceras* sp.? All of the specific determinations are uncertain, as the material is not in a satisfactory condition, but the horizon of the Oriskany sandstone is strongly suggested by the general facies of the fauna.' The following species which Mr. Russell collected at Frog Mountain were also determined by Mr. Walcott, 'Horizon of the Oriskany sandstone of the New York section; *Zaphrentis* sp.?, *Orthis musculosa?*, *Spirifer arenosa*, Conrad, *Pentamerus* cast like that of *P. oblongus*, *Conocardium*.'

"A few miles south of Cedartown, Ga., the stratigraphic relations are shown better than in the disturbed region about Frog Mountain though no fossils have been collected. Resting on the Rockmart slate is a bed of sandstone not more than twenty feet thick, and upon this is a fossiliferous chert which I assumed to be the Fort Payne (Carboniferous). There may be an unconformity above the sandstone or below it or both."

During the past season this region was re-examined and some further conclusions reached, which may be of interest to you. No fossils in addition to those mentioned above were collected, so that the question of the age of these rocks, in so far as it depends on palæontologic evidence, remains essentially as in 1891. Their relations to underlying formations, however, are better understood. The sandstones in question at present rest unconformably upon all older formations of the region, from the Middle Cambrian up to the top of the Lower Silurian. In studying a region so extensively faulted as that between Weisner and Indian Mountains, the natural tendency is to attribute all unconformities to

faulting. And especially is it difficult to discriminate between the broad horizontal thrusts which occur there and deposition overlaps. The work of the past summer has enabled me to make this discrimination in many cases, and has convinced me that the unconformity observed between the sandstone and underlying formations is due generally to deposition overlap and not to faulting. This implies a long period of deformation and erosion between the time represented by the Rockmart slate (probably Hudson River) and the Frog Mountain sandstone, an interval represented elsewhere by the deposition of the Rockwood (Clinton, etc.) which formation to the southward contains heavy beds of conglomerate. This conclusion also strengthens the view, suggested by the fossils mentioned above, that the sandstones of Frog Mountain are of Devonian (Oriskany) age. The uplift which occasioned the unconformity appears to have been along a N.W.–S.E. axis with rather sharp folds transverse to the axis of uplift and in a general way coinciding with folds and faults developed at a much later date.

2. *Marine shell fragments in drumlins near Boston;* by WARREN UPHAM. (Communicated.)—The very interesting paper by Mr. R. E. Dodge in the February number of this Journal (pp. 100–104) draws attention to the greater number of species of Pleistocene fossils found in the section of Winthrop Great Head than in any other drumlin of the Boston Harbor area. This is true, but in a less degree than is supposed by Mr. Dodge, as I am able to state from unpublished observations by Mr. Warren W. Herman of Boston, and from a recently published memoir by Prof. W. O. Crosby (Geology of the Boston Basin, vol. i, Part I, Nantasket and Cohasset, in Occasional Papers of the Boston Society of Natural History, vol. iv, 1893). During the summer of 1891 Mr. Herman spent much time in Winthrop in search for these marine shells, occurring chiefly as glacially broken fragments, in the drumlin sections of Great Head and Grover's Cliff; and he succeeded in finding in each of these hills eight of Dr. Stimpson's original list of fourteen species. Six of this list, namely, the first, second, sixth, and the final three, as given by Mr. Dodge on page 100, were not certainly identified. The most noteworthy difference between these fossils common to the two sections, as shown by Mr. Herman's collections, is the frequency of *Mya arenaria* in Great Head, while it is very rare in Grover's Cliff. In the Great Head section he also found fragments of young specimens of *Scapharca transversa*, several small specimens (about $\frac{1}{3}$ inch long) of a *Lunatia*, one specimen of *Buccinum undatum* (evidently dead and worn, as if cast ashore from outer and deep water, before it was enclosed in the till), one small *Ilyanassa obsoleta*, and one *Crepidula plana* Say, the last being lodged inside a shell of the *Urosalpinx cinerea*. Three of these additional species, and probably also the *Lunatia*, are remarkable in being the same with those of Mr. Dodge.

From three drumlins of Nantasket, namely, Telegraph Hill, Point Allerton Great Hill, and Strawberry Hill, situated five to seven miles southeast of Winthrop, Professor Crosby and Mr. H. D. Card have collected eleven species, the first locality having eight; the second also eight, of which five are found in the first; and the third five, of which four are in each of the two other sections. Only one of these species, *Crucibulum striatum* Say, found only in Telegraph Hill, is an addition beyond the collections of Stimpson, Dodge, and Herman.

The section of the Winthrop Great Head has the highest vertical extent, and therefore affords the most favorable conditions for the preservation of the shell fragments, among all the sections of drumlins in the Boston Harbor district, excepting only the comparatively inaccessible sections of Great Brewster island. To this fact, and to probably more frequent and persistent search than elsewhere, we must ascribe, as I think, the larger list of its discovered species, rather than to greater abundance, either in numbers or in species, of the shells originally supplied to the drift there.

When my previous paper relating to these fossils was contributed to this Journal in May, 1889, I considered them as derived from an interglacial fauna; but it now seems to me more probable that there was no great retreat and re-advance of this portion of the North American ice-sheet, so that these fossils, and the two successive faunas, comprising together about sixty species, at Sankaty Head, Nantucket, would be preglacial. None of these species, however, have become extinct, or undergone important varietal modification, from which it seems certain that no geologically long period has elapsed since their time. In other words, if they are preglacial, the Ice age here, and the epeirogenic uplift which appears to have produced it (this Journal, vol. xlvi, pp. 114–121, Aug., 1893), so far as it affected this part of our coast, were each brief. The uplift, however, farther northeast and north, occupied a much longer time, as is shown by the Fishing Banks and the northern fjords, after which I think that it reached to the latitudes of Boston, New York, Delaware Bay, and beyond, during only a comparatively short stage, when its culmination caused the accumulation of the ice-sheet. That the temperature of the sea at the head of Massachusetts Bay was milder than now, both preceding and following the glaciation, may probably be accounted for, in part or wholly, by the more enclosed and sheltered position of this bay and the whole coast of eastern New England and the eastern provinces of Canada, due to greater height of the Fishing Banks, Newfoundland, and the region of the Strait of Belle Isle.

III. Botany.

1. *Étude sur la constitution de l'appariel fructificateur des Sphenophyllum.* By R. Zeiller. Mém. soc. géol. France, paléont., No. 11, Paris, 1893, pp. 1–39, Pl. I–III.—Although cones of a

number of species of the genus *Sphenophyllum* have since 1804 been figured by various authors, and latterly with partial but not always accurate demonstrations of their structure, the conflict of opinions concerning the systematic position of this most discussed genus has in general been waged on the evidence furnished by the organization, ramification and foliation of the stems and by the superficial features of the cones. Recently, however, largely through the efforts of M. Zeiller, we have been put in possession of so many facts regarding the structure of the true fructification of the genus as to throw great light on its relationship to the rest of the vegetable world.

The additional details of the organization of *Bowmanites* (*Volkmannia*) *Dawsoni* Will., published, not long ago, by Prof. Williamson, (Organization of the Fossil Plants of the Coal Measures, Part XVIII, Philos. Trans. R. Soc., vol. 180, B, pp. 97–101), so impressed M. Zeiller with their striking similarity to those of the cone of *S. cuneifolium* (Stb.) Zeill. (*S. erosum* L. and H.) in which he had in 1888 (Fl. foss. bassin houill. Valenciennes, pp. 415–418, Pl. LXIII, f. 4, 5, 10) detected the union of the bracts in the verticil and the position of the sporangia on the latter, that he reëxamined the Valenciennes material, the result being the announcement in the "Comptes Rendus" for July 11, 1892, of his identification of *Bowmanites Dawsoni* as the cone of *Sphenophyllum cuneifolium*. This correlation of a cone, the structure of which has been so far worked out by Williamson, was promptly admitted by the latter in a short review of the subject in "Nature" of November 3, 1892 (pp. 11–13).

In the present memoir M. Zeiller briefly summarizes the researches of Grand'Eury, Renault, and especially those of Williamson with whose published results he makes a critical and thorough comparison of all the available material. Although confined mostly to opaque specimens he has been able to verify nearly all of Prof. Williamson's discoveries regarding the position and, to some extent, the structure of the parts of the cone, besides contributing much that is new.

Briefly described, the cones of *Sphenophyllum cuneifolium*, the species best known, are 5–10^{cm} or more in length, 8–14^{mm} in width, the diameter of the axis and the internodes each measuring 1·5–2·25^{mm} each. The bracts, which are reflexed for a distance at the base, then curved upward, 6–13^{mm} long, are united for a distance from their origin, forming a funnel. The free ends of the bracts are linear-lanceolate, slender, probably with a median nerve. On the upper surface of these originate the pedicels which curve outward, upward, and then in toward the axis, being adnate for a little distance to the pendant sporangia. The latter, oval, 1–2^{mm} long and ·75–1·25^{mm} wide, are pluriseriate in concentric rings between each pair of verticils, the outer rings being higher than the inner. The sporangium wall is shagreened and slightly spinous. The dorsal surface of the pedicel is, at least near its extremity, formed of thick-walled cells which continue to

the surface of the sporangia, appearing to form a disc which presumably assists in the dehiscence of the microspores found within, the arrangement of the parts being apparently analogous to those of the Eusporangiate ferns. The number of concentric rows of sporangia to each internode varies with the species. In one section two pedicels in the row to one bract were observed. It is not known how the vascular bundle, which seems to be slightly developed in the pedicel, reaches the axis of the cone, nor whether the pedicels branch, though it is thought that in one species at least they do so.

After describing in detail the cones of *S. cuneifolium* M. Zeiller reviews what is known of the fructification of *S. emarginatum*, *S. gracile*, and *S. oblongifolium* on all of which he records new observations. A re-examination of the cone described by Renault (Cours de bot. foss., II, pp. 102, 103), which has considerably influenced opinion as to the relations of the genus, brings both Renault and Zeiller to the conclusion that only one kind of sporangia was present, instead of both macrosporangia and microsporangia as was at first supposed.

Also Zeiller and Williamson agree that the leaves of *Sphenophyllum* are sometimes dissected to the base so as to resemble *Asterophyllites*, a circumstance that led the latter to refer *Bowmanites Dawsoni* to *Asterophyllites*, and which, together perhaps in some instances with vertical burial of the leaves in the matrix, caused Director Stur to maintain that *Sphenophyllum* is the heteromorphous, heterosporous branch of *Calamites*, while *Asterophyllites* is the homomorphous branch, a view somewhat modified by Seward ("Sphenophyllum as a branch of Asterophyllites," Mem. Proc. Manchester Lit. Phil. Soc., 1890).

As to the systematic position of the genus, Williamson in his short note in "Nature" agrees with Zeiller that while the organization of the stem allies it to the Lycopodineæ, its highly specialized fructification brings it nearer the Rhizocarpeæ, and that it forms a distinct class among the Vascular Cryptogams. Kidston, in a recent paper "On the Fructification of Sphenophyllum trichomatosum, Stur, from the Yorkshire Coal Field" (Proc. R. Phys. Soc. Edinb., xi, pp. 56–62, Pl. I), reaches the conclusion that there is no recent order in which the genus can be enrolled, since it differs from the Equisetaceæ by its solid axis and the structure of its cone, from the Lycopods by its ribbed, noded stems with verticillate leaves, while "with the Rhizocarps it appears to have little or nothing in common." He therefore makes the Sphenophylla a peculiar and distinct group, the *Sphenophylleæ*, which though close to the Lycopods can not be included with them. Finally, Zeiller, after considering its resemblance in the development of a secondary or centrifugal growth to the Lycopodinæ the stronger analogy of its fruiting cones to the Hydropterideæ and Ophioglossaceæ, its several characters in common with the Equisetineæ, agrees essentially with the others in constituting for it a distinct class in the Vascular Cryptogams,

and now places it, not between the Equisetineæ and Lycopodineæ as formerly, but next to the Filicineæ on account of the marked affinities it offers in the structure of its cones with the fructification of the Marsileaceæ and the Ophioglossaceæ. D. W.

IV. Astronomy.

1. *The constant of aberration.*—In Bulletin No. 28 of the U. S. C. and G. Survey Mr. Preston gives a detailed discussion of the observations made at Waikiki, H. I., by which a correction is sought for the commonly accepted values of the constant of aberration (20″·445). Mr. Preston says in closing that the definitive result of the constant of aberration from the latitude observations of 1891–1892, made at Waikiki, Hawaiian Islands, on the part of the United States Coast and Geodetic Survey, is therefore

$$\text{Constant of aberration} = 20''{\cdot}433 \pm 0''{\cdot}034.$$

This value of the aberration constant, combined with the latest determinations of the velocity of light (V = 186,330 miles) and Clarke's value for the earth's radius (R = 3963·30 miles), gives the sun's distance and equatorial horizontal parallax as follows:

$$\text{Distance} = 92{,}709{,}000 \text{ miles.}$$
$$\text{Parallax} = 8''{\cdot}82.$$

H. A. N.

V. Miscellaneous Scientific Intelligence.

1. *Sea-water and sea-bottom deposits of the Eastern Mediterranean.*—"The Austro-Hungarian ship *Pola* was again sent out last summer, by the Vienna Academy of Sciences, to the Eastern Mediterranean. Another deep depression has been discovered, this time to the east of the island of Rhodes, in latitude 36° 5′ 30″ N., longitude 28° 36′ E., where the lead gave 3865 mètres (2110 fathoms); and although this depression is apparently shallower than the "Pola-Deep," 4000 mètres (2187 fathoms) in latitude 35° 44′ 20″ N., longitude 21° 44′ 50″ E., to the west of Crete, it is really deeper in relation to the land surrounding it, being fully 7000 mètres (3828 fathoms) below the summit of Ak-Dagh in Anatolia. The new depression is closed to the southeast by a ridge running in a southeasterly direction, which rises to within 1920 mètres (1050 fathoms) of the surface.

As in former years, the chemical character of the sea-water was determined by Dr. K. Natterer, and his investigations appear to him to confirm some previous results, which suggest some remarkable alterations in the accepted theory of the formation of certain geological strata. Dr. Natterer has again been unable to detect the presence of free carbonic acid in any of the samples of sea-water. Since a considerable amount of carbonic acid must be derived from the oxidation of plant and animal remains at the sea-bottom, its absence in the free state can only be explained by supposing that, besides carbonic acid, ammonia is formed, and that in almost equivalent quantities.

These substances, having a tendency to combine, would go to form a corresponding amount of carbonate of ammonium.

Dr. Natterer is inclined to assign the chief part in the formation of not only the partly clayey, partly stony deposits on the sea-bottom, but also of calcareous and siliceous structures in living organisms to precipitates caused by the dissolved carbonate of ammonium. That the mechanical deposition of detritus carried to sea in suspension by surf or by river-waters plays only a subordinate part in comparison with such chemical precipitates (of carbonate of lime, siliceous clay, free silica, etc.), appears especially from the fact that, except near the mouths of rivers, clear water, free from suspended matter, was obtained directly from the water-bottles at all depths in the Eastern Mediterranean; and Dr. Natterer accordingly expresses the view that in the *Porcupine* and *Shearwater* expeditions in 1870–71, it was only because the Sigsbee apparatus was allowed to touch the bottom that fine mud was found in suspension in samples from the lowest layers of water.

The late Dr. W. B. Carpenter, who had scientific charge of those expeditions, ascribes the presence of suspended mineral particles to the fine sand brought down by the Rhone and other rivers (see Proceedings R. S., xix, p. 146, and xx, p. 535). The relatively slight importance of the action of mechanical deposition is further shown by the circumstance that where the chemical conditions necessary for precipitation are absent, mineral particles are dissolved by the sea-water, except when they are present in sufficient quantity to cause the continued reactions observed by Natterer. In fact, the examination of water samples collected at the Tanitic mouth of the Nile, and near the harbor of Port Said, towards which all Nile water is carried by an easterly current, after it reaches the sea showed a surprisingly small amount of suspended matter even in late summer, when the quantity is likely to be large on account of the tropical cloud-bursts. Natterer supposes that the fine sand brought down by rivers is only to a small extent deposited directly, but that for the most part it is first dissolved, and remains in solution until a current carries it to a part of the sea where new conditions bring the separating action into play, and precipitation is caused by the action of living or dead organisms. This process assists in the formation of coral reefs and banks, helps the tide and the surf in the building of dunes, and provides materials for the mineral parts of organisms living in the sea.

Where the sinking of decaying organisms is prevented by a strong current, Natterer supposes that a strong crust is formed on the bottom, instead of the muddy deposits which cover by far the greater part of the Mediterranean basin; and this crust is harder the more slowly it is formed. Samples brought to Vienna prove the existence of intermediate transition stages between the two, and it is suggested that the ammonia, formed by the oxidation of the lower layers of deposits containing decaying organisms in the manner already described, rises to the actual sea-

bottom by diffusion, and there causes the deposition of the stony crust by its action on the sea-water. The crust, which is chiefly composed of carbonate of lime, siliceous clay, and free silica, varies in thickness from about 1·5 centimètres (0·59 inches) to 8 centimètres (3·15 inches), and tends to obliterate the inequalities of the original sea-bottom. Its upper surface is likely to be smooth and clean, while the lower is in immediate contact with the clayey sand.

Dr. Natterer also draws some interesting conclusions from the application of a special chemical method, based on local variations in the amounts of bromine, of iodine, and of nitrous acid contained in sea-water, to the detection and measurement of currents which move too sluggishly to be amenable to direct observations. He has this year been able to subject his method to a severe test in the currents of the Ægean, where it is possible to make direct measurements for comparison; and although the results are not yet fully worked out, the two methods agree very closely. Finally, with regard to the extraordinary poverty of the pelagic fauna of the Mediterranean as compared with the open ocean, Dr. Natterer expresses the opinion that so far as chemical conditions alone are concerned, these are favorable to animal life, and that as a matter of fact a rich fauna occurs in some regions in the immediate vicinity of quite sterile masses of water. It appears that abundant animal life is present just where the water is in rapid motion; and that, generally, the poverty of the Mediterranean fauna is largely due to the want of circulation in its waters—a result opposed to that of Carpenter, who believed it to be due to the excess of suspended matter."—*The Geographical Journal*, vol. iii, pp. 138–140.

2. *Electric Waves; being Researches on the Propagation of Electric action with finite velocity through Space.* By Dr. Heinrich Hertz, Professor of Physics in the University of Bonn. Authorized English Translation by D. E. Jones, B.Sc. With a Preface by Lord Kelvin, LL.D., D.C.L. 8vo, pp. xviii, 280. London and New York, 1893 (Macmillan & Co.).—Probably no greater step in experimental science has been taken in modern times than that which was announced by Dr. Hertz in the spring and summer of 1888 proving the finite velocity of propagation of electromagnetic actions, and showing that these electromagnetic waves in air represent "on a million-fold larger scale the same processes which go on in the neighborhood of a Fresnel mirror or between the glass plates used for exhibiting Newton's rings." The remarkable series of papers in which these discoveries were announced were so much in demand that the publishers of *Wiedemann's Annalen*, in which they appeared, invited him to prepare them for separate publication. This he did under the title: "Untersuchungen über die Ausbreitung der Elektrischen Kraft," adding an introduction and supplementary notes. This admirable book now appears in an English dress; and will be warmly welcomed by English-speaking men of science. Its appearance was almost simultaneous with the death of its brilliant author, Dr. Hertz having died in Bonn on January 1st, 1894, at the early age of 37. G. F. B.

APPENDIX.

ART. XXIII.—*Restoration of Camptosaurus;* by O. C. MARSH. (With Plate VI.)

THE Jurassic deposits of western North America contain the remains of many gigantic Dinosaurs, and various skeletons of these have been obtained by the writer, who has described the more important forms. Restorations of the skeletons of three of the most interesting genera, *Brontosaurus*, *Stegosaurus*, and *Ceratosaurus*, have already been given in this Journal, and another of these huge reptiles is thus represented on Plate VI accompanying the present article. Each of the three forms previously restored was a typical member of a distinct group of the *Dinosauria*, and this is true, although in a less degree, of the present genus, *Camptosaurus*. Restorations of *Anchisaurus* from the Triassic, and *Claosaurus* and *Triceratops* from the Cretaceous, all Dinosaurs of much interest, have likewise been published by the writer in the present Journal.*

The restoration here given is based upon the type specimen of *Camptosaurus dispar*, one of the most characteristic forms of the great group *Ornithopoda*, or bird-footed Dinosaurs. The reptile is represented on Plate VI, one-thirtieth natural size. The position chosen was determined after a careful study not only of the type specimen, but of several others, in excellent preservation, belonging to the same species or to others nearly allied. It is therefore believed to be a position frequently assumed by the animal during life, and thus, in some measure, characteristic of the genus *Camptosaurus*. The present species, when alive, was about twenty feet in length, and ten feet high in the position here represented.

The genus *Camptosaurus* is a near ally of *Iguanodon* of Europe, and may be considered its American representative. *Camptosaurus*, however, is a more generalized type, as might be expected from its lower geological horizon. It resembles more nearly some of the Jurassic forms in England generally referred to *Iguanodon*, but, as these are known only from fragmentary specimens their generic relations with *Camptosaurus* cannot now be determined with certainty.

In comparing *Camptosaurus*, as here restored, with a very perfect skeleton of *Iguanodon* from Belgium, as described and figured, various points of difference as well as of resemblance may be noticed. The skull of *Camptosaurus* had a sharp, pointed beak, evidently encased during life in a horny sheath. This was met below by a similar covering, which enclosed the predentary bone. The entire front of the upper and lower jaws were thus edentulous, as in *Iguanodon*, but of different shape. The teeth of the two genera are of similar

* This Journal, vol. xli, p. 339, April, 1891; vol. xlii, p. 179, August, 1891; vol. xliv, p. 343, October, 1892; and vol. xlv, p 169, February, 1893.

form, and were implanted in like manner in the maxillary and dentary bones. In *Camptosaurus*, there is over each orbit a single supra-orbital bone, curving outward and backward, with a free extremity, as in the existing Monitor; a feature not before observed in any other Dinosaur except *Laosaurus*, an allied genus, also from the Jurassic of America. Other portions of the skull of *Camptosaurus* as well as the hyoid bones appear to agree in general with those of *Iguanodon*.

The vertebræ of *Camptosaurus* are similar in many respects to those of *Iguanodon*, but differ in some important features. In the posterior dorsal region, the transverse processes support both the head and tubercle of the rib, the head resting on a step, as in existing crocodiles. The five sacral vertebræ, moreover, are not coössified, even in adult forms, and to this character the name *Camptonotus* first given to the genus by the writer in 1879 especially refers.* Another notable feature of the sacral vertebræ of the type specimen should be mentioned. The vertebræ of the sacrum, especially the posterior four, are joined to each other by a peculiar peg and notch articulation. The floor of the neural canal of each vertebra is extended forward into a pointed process (somewhat like an odontoid process), which fits into a corresponding cavity of the centrum in front. This arrangement, while permitting some motion between the individual vertebræ, helps to hold them in place, thus compensating in a measure for absence of ankylosis. A similar method of articulation is seen in the dermal scales of some ganoid fishes, but, so far as the writer is aware, nothing of the kind has been observed before in the union of vertebræ.

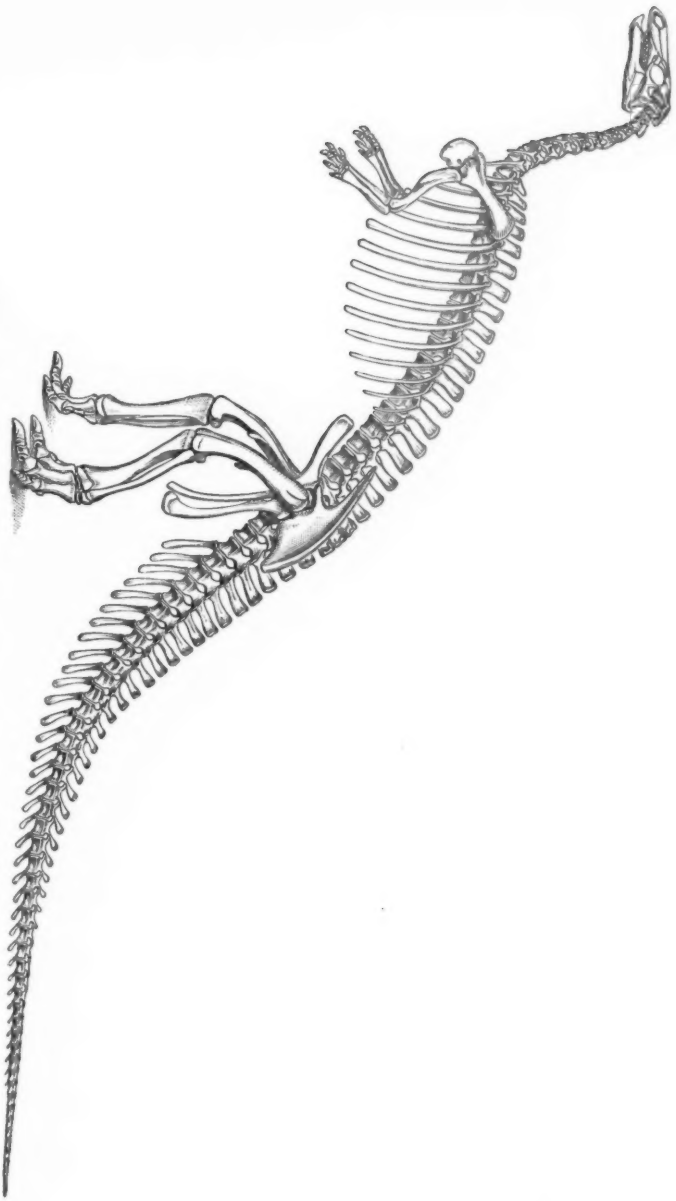
In *Camptosaurus*, the sternum was entirely unossified, and no trace of clavicles has been found. The pelvis of *Camptosaurus* differs especially from that of *Iguanodon* in the pubis, the postpubic branch being even longer than the ischium, while, in *Iguanodon*, this element is much shortened.

In the fore foot of *Camptosaurus*, there were five functional digits, the first being flexible, and nearly parallel with the second, thus differing from the divergent, stiff thumb of *Iguanodon*. The hind feet had each three functional digits only, the first being rudimentary, and the fifth entirely wanting, as shown in Plate VI. The entire skeleton of *Camptosaurus* was proportionately more slender and delicately formed than that of *Iguandon*, although the habits and mode of life of these two herbivorous Dinosaurs were doubtless very similar.

The type specimen of *Camptosaurus dispar*, used as the basis of the present restoration, is from the Atlantosaurus beds of the upper Jurassic of Wyoming. This species and other allied forms will be described in full in an illustrated memoir now in preparation by the writer for the United States Geological Survey. The present restoration is reduced from a large drawing made for that volume.

New Haven, Conn., February 23, 1894.

* This name proved to be preoccupied, and *Camptosaurus* was substituted for it This Journal, vol. xxix, p. 169, February, 1885.



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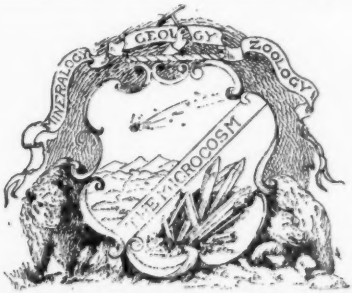

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